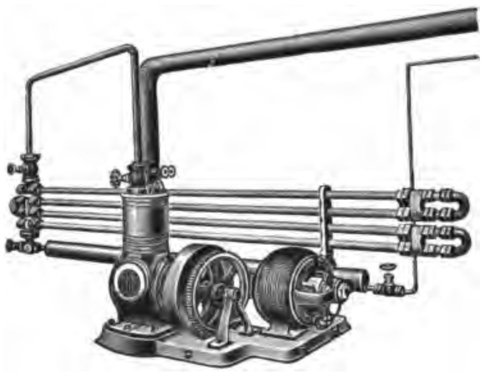
LOOK WITHIN

TRADE MARK

Refrigeration and Ice Making

IN TWO VOLUMES.

VOL. ONE



With kind compliments

PROF. Dr CARL V. LINDE

MUENCHEN

The [illegible] Information is in the Answer

Audels

ON

Refrigeration and Ice Making

A PRACTICAL TREATISE

with ILLUSTRATIONS

BY

GIDEON HARRIS

and Associates

VOL. ONE

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DEDICATION

This work is respectfully dedicated to

CHARLES EDWIN BOOTH, ESQ.

President of the Seaboard Refrigeration Company of New York City, in appreciation of his practical assistance given during the progress of the book through the press, as well as of personal esteem for the high attributes of manhood which have been displayed by him through a wide experience.

CONTENTS VOLUME ONE.

FOR ALPHABETICAL INDEX, SEE PAGE 651.

INTRODUCTORY.

THIS work is designed to be an introduction to what is generally acknowledged to be a difficult branch of applied science.

The embarrassment of the student, or practical man in charge, does not lie so much in its laws, or in its nomenclature, or indeed in any one feature so much as in a neglect to patiently acquire a familiarity with the first principles of natural philosophy involved in the processes.

In view of this the author has aimed to make the work one of instruction and reference; not only detailing the present status of the art, but it has also been his aim to arrange the subjects separately and in natural order, like the successive steps of a ladder leading to a height from which could be viewed the whole science, as though it were a single landscape.

Nor has he forgotten that refrigeration like any other mechanical science rests upon experiment, and its laws grow out of logical deductions from careful and repeated research.

The United States is preeminently the field where mechanical refrigeration has had its widest and most rapid growth; a fact due to several causes, such as variability and diversity of climate; high standard of living; facilities for interchange of products between distant localities; variety of food products; the national liking for iced drinks; the householder's provident

habit of getting considerable supplies at a time instead of buying each day only the quantity needed for that day as is the custom of other lands; and lastly the promptings of American inventive genius and commercial enterprise.

It may safely be assumed that the comparatively new science which forms the subject of this treatise is one that will develop into a special industry of vast proportions that will have no end, until the present organized constitution of the globe is essentially changed.

The rate of progression and the particular lines of advancement must, owing to the nature of things, remain unknown; suffice it that the time is not far distant when men will wonder that the world was ever able to exist without its aid.

The art of obtaining temperatures above that of the surrounding atmosphere is as old as the dawn of history, but methods of keeping temperatures below the surrounding atmosphere are comparatively modern.

Before 1880 natural sources of cold, such as ice from rivers and lakes, were employed to some extent to preserve food, but operations were limited to a few food products, and the period for storing most of them was restricted. The large space required for an ice storage house, together with the limited range and imperfect control of temperature, rendered impossible the extensive and varied operations now made easy by employment of mechanical means of refrigeration. Besides this, ignorance and neglect of the importance of ventilation and regulation of atmospheric moisture made out of the question then such perfect preservation of goods as is now easily accomplished. The

application of the principles of thermodynamics to the business of preserving food products in their natural condition rivals in the success and importance of its results any of the achievements of science in the wide realm of the world's economies and comforts. It has provided a balance wheel to equalize and distribute the load between food demand and food supply.

Popular notions of heat seem to start from the temperature of the living human body as their initial point.

If we are in contact with a substance having a lower degree of sensible heat than ourselves, heat passes from us to it, producing the sensation we call cold; if we are in contact with a body of higher temperature than ourselves, we feel an inflow of heat from it to us, and call the thing hot.

In what way is refrigeration a benefit in the economy of nature and demands of modern business?

First, to prevent premature decay of perishable products. The immense fruit trade of the Pacific coast could never have been developed without its assistance, nor could the surplus meat products of the southern hemisphere be brought half way around the globe without its aid. In fact everywhere the production of fruit, meat, eggs, and other food products would be greatly curtailed if it were not for the fact that the use of refrigeration establishes a constant market.

Second, to lengthen the period of consumption. In many classes of produce the usual season of consumption was formerly limited to the immediate period of production. At the present time, however, a great variety of fruits, dairy and other products may be had in good condition and at reasonable prices the year round.

Third, it enables the owner to market his property at will, or he can put in cold storage a portion or all his products to

await a suitable time for selling. This is for the advantage of the consumer as well as the producer, for it prevents very great fluctuations in price during the year.

Fourth, it makes transportation in good condition possible for long distances from the place of production to large centers of population. The fruit trade of the world could not exist without it.

What is the meaning of refrigeration?

Refrigeration is the process of reducing the temperature of any substance below that of the surrounding atmosphere, and, if necessary, keeping it within certain narrow limits; in other words, controlling its temperature.

How may the process of refrigeration be brought about?

One of the oldest methods is the melting of ice, or the dissolving of certain salts in water producing solutions which are called frigorific mixtures. Another is the absorption of heat when work is done, as by working a piston against resistance by a compressed gas, as seen in air machines. A third method is by transferring heat from a warmer body to a colder one, as by the circulation of cold brine.

The last method is the most important one, mechanically, which is by evaporating liquids which have low boiling points. This is the principle on which nearly all modern refrigerating machinery is based.

How is refrigeration of benefit to the health and comfort of mankind?

It places at one's command a greater variety of food during all seasons of the year.

What other ways are there of food preservation?

Drying, smoking, salting, use of sugar and vinegar, exclusion of air (canning), by use of antiseptics, chemicals, etc.

Why is refrigeration superior to all these?

It adds or subtracts nothing from the article preserved, it causes no change of appearance or taste, and leaves it as nutritious and digestible as it was at first, which cannot be said of most of the other methods.

What is "natural" ice?

Ice which forms on the surface of ponds, rivers, lakes, etc., during the winter season.

What is necessary for its formation?

That the temperature of the air shall fall to the freezing point of water and remain there some time.

Why does not the freezing take place as soon as the atmospheric temperature drops to 32° Fahr.?

Because water contains 142 degrees of latent heat which it must give up before freezing can take place.

What is noticed in the liquefaction of vapors?

When vapors are liquefied the heat which becomes latent during evaporation appears again and must be removed by cooling.

Vapors of liquids, the boiling point of which is above the ordinary temperature, can be liquefied at the ordinary temperature without additional pressure, that is by distillation or condensation. Permanent gases require additional pressure, and in some cases considerable refrigeration to become liquefied.

What is ebullition?

If the temperature be high enough the vaporization takes place all through the liquid by the rapid production of bubbles of vapor. This phenomenon is called ebullition, and it will take place at a constant temperature for the same liquid, pressure conditions being the same.

What is the boiling point?

The temperature at which ebullition takes place at a given pressure. Speaking generally of the boiling point we mean under ordinary conditions at the sea level pressure.

How does the boiling point vary?

It varies with the nature of the liquid and always increases with the pressure. It is not affected by the source of heat for the temperature of the liquid will not rise above the boiling point as long as ebullition is going on. The heat which is imparted to the liquid, and which seems to disappear, is called the latent heat of vaporization.

How may the boiling point be elevated?

Substances held in solution will elevate the boiling point. A saturated solution of chloride of sodium boils at 226° and one of chloride of calcium at 370° F.

Freedom from gases has a tendency to raise the boiling point of water, and it may be heated to 260° before it begins to boil. This fact should be guarded against in operating boilers or it may cause an explosion.

UNDERLYING PRINCIPLES

OF

REFRIGERATION.

In applying the laws of science to any of the live applications of modern industries, it is inevitable that reference must first be made to certain decrees of nature which operate with absolute accuracy in their minutest stage as well as in the largest—hence the following :

Matter is any collection of substance existing by itself in a separate form ; matter appears to us in different forms which, however, can all be reduced to three classes, namely, solids, liquids, gases ; a solid offers resistance to change of shape, always keeping the same size or volume and the same shape ; a liquid is a body which offers no resistance to a change in shape, and a gas or vapor is any substance in the elastic or air-like condition.

The difference between a gas and a vapor is one less of kind than of degree. It is important to note that experiment proves that every vapor becomes a gas at a sufficiently high temperature and low pressure, and, on the other hand, every gas becomes a vapor, at sufficiently low temperature and high pressure.

The two essential properties of matter, both of which are inseparable from it, are extension and impenetrability. Extension, in the three dimensions of length, breadth, and thickness, belongs to matter under all circumstances ; and impenetrability, or the property of excluding all other matter from the space which it occupies, appertains alike to the largest body and the smallest particle.

The limits of useful knowledge relating to the properties of matter may be found in the three following definitions :

An *elementary body* is one which cannot be resolved into two or more different substances ; they are also called elements or simple bodies.

An *atom* is the smallest particle of matter capable of entering into or existing in combinations. It is the unit of matter of the chemist.

A *molecule* is the smallest quantity of an elementary or compound body which is capable of an independent existence. It is usually a compound of several atoms of different elements or perhaps the same element. It is the unit of matter of the physicist.

The quantity of matter which a body contains is called its *Mass ;* the space it occupies, its *Volume ;* its relative quantity of matter under a given volume, its *Density.* All bodies have empty spaces denominated *Pores.*

In solids, we may often see the pores with the naked eye, and almost always by the microscope ; in fluids, their existence can be proven by experiment ; there are reasons for believing that even in the densest bodies, the amount of solid matter is small compared with the empty spaces, hence it is inferred that the particles of matter touch each other only in a few points.

There are also several other properties which are known by experience to belong to all matter, as *gravity*, *inertia*, and *divisibility ;* and others still which belong not to matter universally, but only to certain classes of bodies, as *elasticity*, *malleability*, or the power of being extended into leaves or plates ; and *ductility*, or the power of being extended in length, as when drawn into wire.

The *mass* of a body, or the quantity it contains is a constant quality, while the *weight* varies according to the variation in the force of gravity at different places.

Physics is that branch of science which treats of the laws and properties of matter and the forces acting upon it ; especially

that department of science (known, formerly, as Natural Philosophy) which treats of the causes that modify the general properties of the bodies.

The object of physics is the study of phenomena presented to us by bodies ; it should, however, be added that changes in the nature of the body itself, such as the decomposition of one body into others, are phenomena whose study forms the more immediate object of chemistry.

Mechanics is that section of natural philosophy or physics which treats of the action of forces on bodies.

That part of mechanics which considers the action of forces in producing rest or equilibrium is called *statics ;* that which relates to such action in producing motion is called *dynamics.* The term *mechanics* includes the action of forces on all bodies, whether solid, liquid, or gaseous. It is usually, however, used of *solid bodies* only. Applied mechanics is the practical use of the laws of matter and motion in the construction of machines and structures of all kinds.

The mechanics of liquid bodies is also called hydrostatics or hydrodynamics, according as the law of rest or of motion is considered. The mechanics of *gaseous bodies* is called also pneumatics. The mechanics of fluids in motion with special reference to the methods of obtaining from them useful results constitutes hydraulics.

As there are three states of matter already described, *i. e.*, solids, liquids, gases, so there are three laws of motion. These are as follows :

LAW 1. "Every body continues in its state of rest, or of uniform motion in a straight line, except in so far as it is compelled by force to change that state."

LAW 2. "Change of (quantity of) motion is proportional to force, and takes place in the straight line in which the force acts."

Law 3. "To every action there is always an equal and contrary reaction ; or the mutual actions of any two bodies are always equal and oppositely directed."

The above are "Newton's Laws."

Law 1, tells us what happens to a piece of matter left to itself, *i. e.*, not acted on by forces ; it preserves its "state," whether of rest or of uniform motion in a straight line. The first law gives us also a physical definition of "time," and physical modes of measuring it.

Law 2, tells us—among other things, how to find the one force which is equivalent, in its action, to any given set of forces. For, however many changes of motion may be produced by the separate forces, they must obviously be capable of being compounded into a single change and we can calculate what force would produce that.

Law 3, furnishes us with the means of studying directly the transference of energy from one body or system to another. Experiment, however, was required to complete the application of the law.

The following definitions and general considerations relate especially to the mechanics of refrigeration :

Attraction. This is an invisible power in a body by which it draws anything to itself ; the power in nature acting naturally between bodies, or particles, tending to draw them together ; the attraction of gravitation acts at all distances throughout the universe ; *adhesive attraction* unites bodies by their adjacent surfaces ; *chemical attraction,* or chemical affinity, is that peculiar force which causes elementary atoms or molecules to unite.

Cohesion is that force which binds two or more bodies together. It is that force which the neighboring particles of a body exert to keep each other together.

Ductility is that property by which some metals can be drawn out into wire or tubes.

Elasticity is the property possessed by most solid bodies, of regaining their original form or shape, after the removal of a force which caused a change of form.

Energy is the capacity for performing work ; the *kinetic energy* of a body is the energy it has in virtue of being in motion ; kinetic energy is sometimes called *actual energy ; potential energy* is energy stored up as that existing in a spring or a bent bow, or a body suspended at a given distance above the earth and acted upon by gravity.

Force is that which tends to produce or to destroy motion ; if a body is at rest anything which tends to put it in motion is a force ; *centrifugal force* is that by which all bodies moving around another body in a curve, tend tc fly off from the axis of their motion ; *centripetal* is that which draws, or impels a body toward some point as a center ; *force* is equivalent to *push* or pull.

Fatigue of Metals. In many cases materials are subject to impulsive loads and a gradual diminution of strength is observed ; in part this deterioration of strength may be due to the ordinary action of a live or repeated load, but it appears to be more often due directly to the gradual loss of the power of elongation in consequence of the slow accumulation of the *permanent set ;* the latter may be defined as the *fatigue of metals.*

Friction is that force which acts between two bodies at their surface of contact so as to resist their sliding on each other, and which depends on the force with which they are pressed together.

Gravity. We can not say what gravity *is*, but what it *does*,—namely, that it is something which gives to every particle of matter a tendency toward every other particle. This influence is conveyed from one body to another without any perceptible interval of time. We weigh a body by ascertaining the force

required *to hold it back*, or to keep it from descending ; hence, also, weights are nothing more than *measures of the force of gravity* in different bodies.

Load. By the load on any member of a machine is meant the aggregate of all the external forces in action upon it. These may be distinguished as (1) the *useful load*, or the forces arising out of the useful power transmitted, and (2) the *prejudicial resistances* due to friction, to work uselessly expended, to weight of members of the machine, to inertia due to changes in velocity of motion, and to special stresses caused in the apparatus by changes in its parts through variations of temperature.

There are two kinds of load : first, a *dead load* which produces a permanent and unvarying amount of straining action, and is invariable during the life of the machine—such, for example, as its weight ; and, second, variable or *live load*, which is alternately imposed and removed, and which produces a constantly varying amount of straining action.

Every load on a structure produces a change of form, termed the strain due to the load. The strain may be either a vanishing or elastic deformation, that is, one which disappears when the load is removed ; or a permanent deformation or set, which remains after the load is removed. In general, machine parts must be so designed that, under the maximum straining action, there is no sensible permanent deformation.

The *Breaking Load* is that load which causes in those fibres which are subjected to the greatest strain, a tension equal to the Modulus of Rupture ; in every case this is equal to the force necessary to tear, crush, shear, twist, break, or otherwise deform a body.

Momentum means impetus or push ; it is the quantity of motion in a moving body ; it is always proportioned to the quantity of matter multiplied into the velocity. *Moment* is the tendency, or measure of tendency, *to produce motion*, especially motion about a fixed point or axis.

Power is the rate at which mechanical energy is exerted or mechanical work performed, as by a steam engine, an electric motor, etc.

Ultimate Strength. If the straining action on a bar is gradually increased till the bar breaks, the load which produces fracture is called the ultimate or breaking strength of the bar. That ultimate strength is for different materials more or less roughly proportional to the elastic strength. We may insure the safety of a structure by taking care to multiply the actual straining action by a factor sufficiently large to allow, not only for unforeseen contingencies and the neglected causes of straining, but also for the difference between the elastic and ultimate strength. The actual straining action multiplied by this factor is termed a *factor of safety,* and is then equated to the ultimate strength of the structure ; the value of the factor of safety must be determined by practical experience.

The *Co-efficient of Safety* is the ratio between the theoretical resistance and the actual load, or, what amounts to the same thing, the ratio between the elastic limit and the actual tension of the fibres. The *Factor of Safety* is the ratio between the breaking load and the actual load. As a general rule, for machine construction, the Co-efficient of Safety may be taken as double that which is used for construction subjected to statical forces.

The *Strength of Materials* entering into machine construction is measured by the resistance which they oppose to alteration of form, and ultimately to rupture, when subjected to force, pressure, load, stress or strain.

Stress is the re-action or resistance of a body due to the load.

Strain is the alteration in shape, as the result of the stress.

Tenacity is the resistance which a body offers to being pulled asunder, and is measured by the tensile strength in pounds per square inch of the cross section of the body.

Tensile Strength is the resistance per unit of surface, which the molecular fibres oppose to separation.

Velocity is the rate of motion ; in kinematics, *speed* is sometimes used to denote the amount of velocity without regard to direction of motion, while *velocity* is not regarded as known unless both the direction and the amount are known.

Linear Velocity is the rate of motion in a straight line, and is measured in feet per second, or per minute, or in miles per hour. *Circular velocity* is the rate at which a body describes an angle about a given point, and is measured in feet per second or per minute, or in number of revolutions per minute, as in a pulley or shaft. *Uniform velocity* takes place when the body moves over equal distances, in equal times. *Variable velocity* takes place when a body moves with a constantly increasing or decreasing speed.

Work is the overcoming of a resistance through a certain space, and is measured by the amount of the resistance multiplied by the length of space through which it is overcome. The *Principle of Work:* The foot-pounds of work applied to a machine must equal the number of foot-pounds of work given up by the machine plus the number absorbed by friction. The simplest possible example of doing work is to raise a weight through a space against the resistance of the earth's attraction, that is to say, against the force of gravity.

For instance, if a hundred pounds be raised vertically three feet, work is done, and, according to the above, the amount of work done is measured by the resistance due to the attraction of the earth or gravity, *i. e.*, one hundred pounds, multiplied by the space of three feet, through which it is lifted. The product formed by multiplying a pound by a foot is called a foot-pound. Thus, in the above instance, the amount of work done is 300 foot-pounds. Had the weight been only three pounds, but the height to which it was raised 100 feet, the quantity of work done would have been precisely the same, *i. e.*, 300 foot-pounds.

How are the chemical elements expressed?

By symbols taken from the initial letters of their Latin or English names.

What is the symbol of water and what does it show?

H_2O; it shows that the molecule of water contains two atoms of hydrogen and one atom of oxygen.

What is the measure of affinity?

The amount of heat or other energy developed during a chemical change.

What is atomic weight?

The weight of an atom as compared with hydrogen.

What is valence or atomicity?

That property of an element by virtue of which it can hold in combination a certain number of other atoms. The atomicity of hydrogen being taken as the unit the atomicity of an elementary body is measured by the number of atoms of hydrogen which its atom can hold in combination.

What is sublimation?

The change of a solid into a condition of vapor without passing through the liquid state is called sublimation. Camphor, ice or snow may be sublimated or sublimed.

What is dissociation?

This word indicates the separation of a chemical compound into its constituent parts, especially if it has been necessary to subject the compound to a high temperature.

What is the buoyancy of liquids?

The upper layer of a liquid not only exerts a pressure on the lower layers, but it also exerts a pressure in an upward direction. This phenomenon is called the buoyancy of liquids.

How is the composition of a molecule shown?

By the symbols of its constituents. The number of atoms is expressed by inferior figures at the right of the symbol, and if we know the atomic weight of each symbol we can easily calculate the percentage composition.

Describe the term gas.

A gas is a body in which the molecules are so far apart that their dimensions may be neglected. They are constantly vibrating to and fro, and the average momentum or energy of this motion represents the temperature of the gas, and the force with which they impinge on the walls of the vessel in which they are inclosed shows the pressure of the gas.

What is the most noticeable difference between a liquid and a gas?

A liquid has no tendency to occupy any more space, although it yields readily to change of form; a gas, on the other hand, will at once expand and occupy any vessel in which it is put, and as a natural consequence, is easily compressible.

Define fluids.

Fluid is a term including both gases and liquids. It designates a body whose molecules may be displaced by a very slight application of force, this property being called fluidity. It is possessed in a much greater degree by gases than by liquids.

What is combustion?

A rapid combination of a combustible material with oxygen.

What is necessary to start it?

To elevate its temperature or bring it in contact with a burning body.

If it undergoes combustion without ignition it is a case of spontaneous combustion, and if it takes place without the appearance of flame or light it is called slow combustion.

What is the surface tension of liquids?

The layer of a liquid which separates the same from a gas or a vacuum has a greater cohesion than any other layer of the liquid, owing to the fact that the attraction exerted on this layer by the interior of the liquid is not counteracted by any attraction on the outside.

The surface of the liquid is practically covered by an elastic skin which exerts a pressure on the interior, this pressure being termed the surface tension. It is greater as the cohesion of the liquid increases.

What is saturated vapor?

A vapor is saturated when it is still in contact with some of its liquid; vapors in this state are at their greatest density for that temperature.

If a saturated vapor be compressed, without change of temperature, a proportionate amount of liquefaction will be produced, but if the temperature be allowed to rise corresponding to the work done by compression, the vapor becomes superheated.

What is wet or moist vapor?

A vapor which holds in suspension particles of its liquid is called wet or moist vapor.

What is a superheated vapor?

Vapors which are not saturated are called dry or superheated and act like permanent gases.

What is vapor tension?

Vapors have elastic foice like gases, and in consequence they exert a certain pressure on surrounding surfaces.

This varies with the nature of the liquid and the temperature; it is called the tension of the vapor.

What is the difference between a gas and a vapor ?

When a substance first changes from the liquid to the gaseous state, or while the pressure, volume and temperature are near those corresponding to such a change, the substance is more strictly called a vapor, or said to be in the vaporous condition. If the substance is in the gaseous state, but with pressure, volume and temperature conditions far removed from those corresponding to the change of state, the substance is more generally called a gas. There is no sharp line of difference between a vapor and a gas.

What is vaporization ?

A liquid exposed to the atmosphere or a vacuum will give off vapors until the space above the liquid contains vapor of the maximum density for the temperature.

What do we mean by gaseous steam or steam gas ?

Steam that is highly superheated ; it then assumes the gaseous state.

What did Archimedes discover ?

That a body weighed in a liquid would lose a part of its weight equal to the weight of the liquid displaced.

How is this fact used in determining the volume and specific gravity of irregular-shaped solid bodies ?

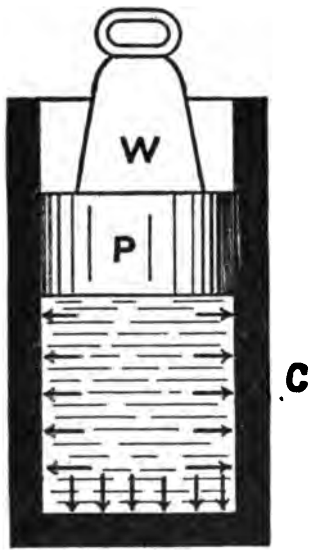
If a body be weighed in air and then in water, its volume is equal to the bulk of water corresponding to the lost weight. The specific gravity may then be ascertained by dividing its weight in air by the loss of weight which it sustains by being weighed under water.

How is the law of Archimedes still further applied ?

A body lighter than air will rise, as a balloon for instance.

What is Pascal's law?

Pressure exerted anywhere on a liquid is transmitted in all directions and acts with the same force on all equal surfaces at right angles to them.



The pressure exerted by the liquid in the cylinder C, due to the weight W placed on the piston P, is indicated by the arrows. The pressure per unit area equals the weight divided by the area of the piston.

What is Dalton's law for vapors?

The amount of vapor of a certain substance which will saturate a given space is the same whether the space be a vacuum or already occupied by a gas. The tension of the mixture is equal to the sum of the tensions which each would possess if it occupied the same space alone.

What is viscosity?

A tendency for particles to drag adjacent particles along, due to internal friction.

What is the latent heat of expansion ?

When a gas expands while doing work, such as propelling a piston, an amount of heat equivalent to the work done becomes latent or disappears. This is the latent heat of expansion.

What is a vapor ?

A volatile substance above its critical temperature is called a gas, below it a vapor.

What is a more popular conception of a vapor ?

Gaseous bodies are generally spoken of as vapors when they are near the point of maximum density, and they are often still further distinguished as saturated, superheated and wet vapors.

How will two gases mix ?

If brought together they will mix thoroughly, and the pressure on a vessel containing them will be the sum of the pressures of both.

What is the specific heat of gases ?

A gas may be heated while its volume is kept constant and also while its pressure remains constant.

In the former case the pressure increases and in the latter the volume increases. In the former case the heat added is only used to increase the momentum of the molecules, while in the latter case an additional amount of heat is required to do the work of expanding the gas against the pressure of the atmosphere.

What are inflammable bodies ?

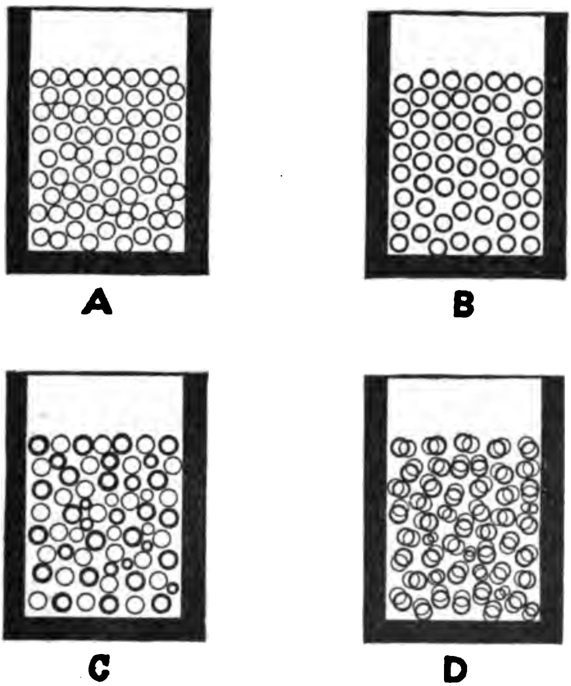
Those in which combustion starts very easily by merely slight contact with a flame.

What are explosive bodies ?

Those in which a large volume of gas is suddenly evolved, and instantaneous combustion takes place throughout the entire mass.

What is chemical combination?

When the molecules of one or more elementary bodies break up and form new molecules in a substance whose properties are entirely different from the original substances.



If we mix the two different liquids in the vessels A and B, together, and they form a mixture which may be separated again by mechanical means such as distillation or a sedimentary deposit, such a mixture is called a mechanical one, as is shown at C, the molecules simply mixing as indicated by the light and heavy circles.

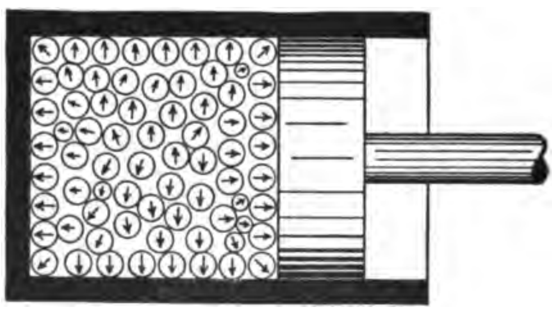
If, however, the molecules of the two liquids combine together to form molecules of a different composition, each consisting of the atoms which formerly constituted the molecules of the separate liquids, the resulting matter is called a chemical combination, which can only be decomposed by a chemical process or high temperature. Such a composition is graphically indicated at D.

What is Avogadro's law?

Under similar conditions of temperature and pressure equal volumes of all true gases contain the same number of molecules, hence the molecular weights of gases are proportional to their densities.

What is an ideal cycle?

When the working substance returns periodically to its original condition and may be used over and over continuously. If at the same time the operations of the cycle are carried on reversibly the conversion of heat into work takes place at the greatest possible rate. As we can only approach it practically it is called the ideal cycle.



The small circles represent the molecules of a gas; the arrow head represents the manner in which the pressure is exerted upon the interior surface of a cylinder and upon a piston by the expansion of the gas due to its molecular motion.

What is a reversible cycle?

If all the changes or operations can be carried out in a reverse direction the cycle is called a reversible one.

Not all changes can be performed in this manner, however, but they can generally be made so, at least in theory, if the transfers of heat follow only very small differences in temperature, and the changes in volume take place under very small differences in pressure.

MATERIALS AS APPLIED

TO

REFRIGERATION.

The above word is derived from the old English term *matter*, meaning that which makes up the substance of anything, especially the matter which forms or may form a part of some material structure, as a machine or building.

It may be said that matter is anything that occupies space or enters into the composition of the physical universe. It is not possible to convey in words a fundamental idea of the various material substances which enter into the successful operating of a modern ice or refrigerating plant, but it may be added that—

The properties of matter and the laws and forces by which it is controlled are the important considerations well to be known. Most forms of matter can be seen, felt or perceived in other ways. Any one kind of matter is called a substance or material. Iron, wood, glass, and gases are examples of substances ; there are strong reasons for believing that matter is composed of a great number of very small particles called molecules. A body may be solid, a liquid or a gas, depending on the rapidity of the motion of its molecules. This is discussed more fully in the chapter on heat and cold.

What is ammonia ?

Ammonia is a colorless gas with a characteristic pungent odor (hartshorn), and a marked alkaline taste. It has a specific gravity of 8.5 (hydrogen being 1) and is lighter than air. It burns in oxygen, producing water and nitrogen, and is a powerful base, combining with all acids to form salts. Ammonia is easily liquefied at ordinary temperatures, a pressure of seven atmo-

spheres being sufficient ; it is also the most soluble of gases, one volume of water dissolving over 800 volumes of it at ordinary temperature. It is obtained on a commercial scale by boiling the ammoniacal liquor of gas works with milk of lime, or recovered from the by-products of blast furnaces and coke ovens. Ammonia is used largely in the process of refrigeration—as explained hereafter.

What is ammoniacal liquor ?

Ammoniacal Liquor is an aqueous solution of numerous complex substances, also known as coal tar liquor, of which ammonia is the base ; it collects in the condensers and scrubbers during the manufacture of illuminating gas from coal, and hence is also known as *gas liquor*. Some of the ammonia compounds are volatilized along with the free ammonia by boiling the liquor. Others are removed by boiling with milk of lime.

What is carbonic acid ?

Carbonic Acid is a weak and unstable acid formed by part of the carbon dioxide when dissolved in water. Hence carbon dioxide is termed *carbon anhydride*, as it is the *anhydride* of this acid, and also for the same reason *carbonic acid gas*. Carbonic acid is extensively used, especially in marine refrigeration.

What is carbon dioxide ?

Carbon Dioxide is a colorless compound of gas heavier than air, neither combustible nor a supporter of combustion. It is evolved by the combustion of fuels containing carbon, one atom of that element combining with two of oxygen from the air, to form this gas ; it is exhaled by respiration from the lungs ; is poisonous if *inhaled*, as it prevents the blood from receiving its proper oxygen.

What is sulphurous acid?

Sulphurous acid is a gas used in refrigeration, consisting of two equivalents of oxygen and one of sulphur, formed by burning sulphur in air or dry oxygen. Sulphurous acid is easily liquefied, is incombustible, has no chemical action upon metals or fats, is a good lubricant and is cheaply made; but it has the great disadvantage of requiring a very large compressor, nearly three times as large as with an ammonia plant of the same power.

What is Pictet's liquid?

A liquid composed of about three per cent. of carbonic acid and ninety-seven per cent. of sulphurous acid. It is a compound made for refrigerating purposes only, and will be described hereafter.

What is ether?

Ether is a colorless volatile liquid, distilled from a mixture of sulphuric acid and alcohol, and hence sometimes known as sulphuric ether. It is used as an anæsthetic, by inhalation, being safer than chloroform; or to cause local refrigeration and anæsthesia by spraying and evaporation. In refrigeration, ether is used in ice machines, for which purpose it possesses certain important advantages, but these are more than outweighed by its inflammability and liability to explosion when mixed with air.

What is air?

Air is a gas consisting of a mechanical mixture of 23 per cent. of *oxygen* (by weight), 76 per cent. *nitrogen*, and 1 per cent. *argon*. Carbonic acid is present to the extent of about .03 or .04 per cent. of the volume. Obscure constituents are .01 per cent. *krypton* with small amounts of several other gases. It is used for refrigerating purposes in its original form; its advantages and disadvantages as compared with ammonia and carbonic acid will be referred to hereafter.

What is salt ?

Salt is the chloride of sodium, a substance used for seasoning food, for the preservation of meat, fish, etc. It is found native in the earth, and is also produced by evaporation and crystallization from sea water and other water impregnated with saline particles. Its special advantage in refrigeration is that a solution of it in water prevents the water from freezing above a zero temperature.

What is calcium chloride brine ?

Calcium Chloride Brine in refrigeration, is used preferably to a solution of sodium chloride (common salt), as it is a more energetic moisture absorber than the latter, and does not rust the tanks or coils. A 20 per cent. solution is the usual strength and a temperature of 8° to 18° F. is maintained, with an average of 14° F. Hereafter in describing the various systems of refrigeration much will be said comparing the different merits of salt brine solutions of sodium and calcium.

What is water ?

Water is a colorless transparent liquid composed of the two gases, hydrogen and oxygen. It freezes at 32° Fahr., or 0° C., and boils at 212° Fahr., or 100° C. The following general laws governing the action and state of water are important : (a) Water is practically non-elastic, experiment appears to show that for each atmosphere of pressure (14 7-10 lbs.) it is condensed 47½ millionths of its bulk ; (b) water at rest presses equally in all directions ; (c) a given pressure or blow impressed on any portion of a mass of water confined in a vessel is distributed equally through all parts of the mass ; (d) the surface of water at rest is horizontal ; (e) the pressure on any particle of water is proportioned to its depth below the surface ; (f) water rises to the same level in the opposite arms of a recurved tube ; (g) any

quantity of water, however small, may be made to balance any quantity however great.

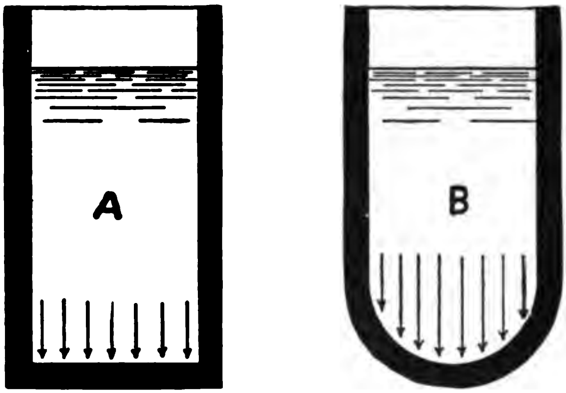
It is necessary that an abundant supply of water be available in all the systems of refrigeration.

What is steam ?

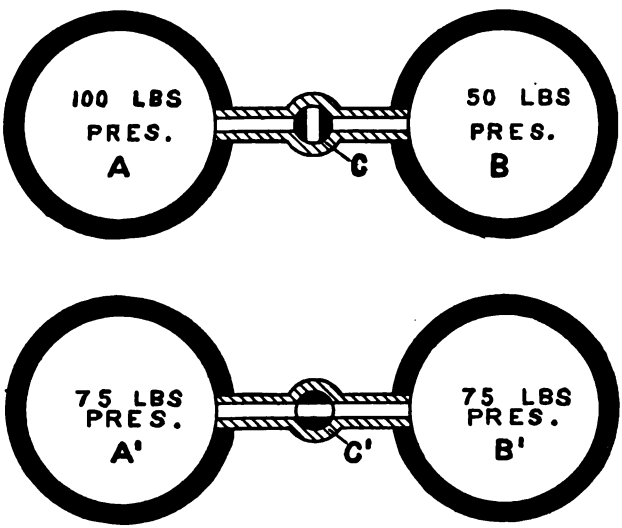
Steam is the vapor of water ; the hot invisible vapor given off by water at its boiling point, this latter depending upon the pressure. The visible white vapor termed steam, is really a collection of fine watery particles, formed by condensation of true steam. When water is evaporated within a closed space, the process will continue up to a certain point, when the steam is said to be *saturated*, this signifying that no more steam can be made, unless the temperature be raised or the pressure lowered, by permitting some of the steam to escape.

The distinguishing properties of steam are : (1) Its fluidity, (2) its mobility, (3) its elasticity, and (4) its equality of pressure in every direction ; that is, steam has a flow like water, it has a circulation within its own body, it is capable of compression and expansion, and when it is confined it presses equally upon all parts of the restraining vessel. Each molecule of steam is composed of two gases which have neither taste nor color. The difference in volume between water and steam at atmospheric pressure is as 1646 to 1 ; that is, a given quantity of water expanded into steam will occupy 1646 times the space it did before. This is nearly one cubic foot, and one cubic foot of steam at atmospheric pressure weighs .038 lbs.

Steam is said to be : (1) *saturated* when its temperature corresponds to its pressure, (2) *superheated* when its temperature is above that due to its pressure, (3) *gaseous steam* or *steam gas* when it is highly *superheated*, (4) *dry* when it contains no moisture. It may be either saturated or superheated, (5) *wet* when it contains intermingled mist or spray, its temperature corresponding to its pressure.



A and B are two cylindrical vessels filled with the same liquid; the arrows indicate the direction the liquid exerts its pressure upon the bottom of the vessels. It is clear that the pressure at the centre of B is equal to that per unit area of A, but toward the sides the pressure decreases as the depth decreases.



The two vessels A and B are connected by a pipe having a cock C. A contains air at 100 pounds pressure while B contains a gas at 50 pounds pressure. If the cock C is now opened the air in A will at once rush over to B until the pressure in both vessels is equalized at 75 pounds, which is one-half the sum of the former pressures.

HEAT AND COLD.

Cold is simply the absence of heat, and, in a strictly scientifie light, should be treated of under the head of *heat;* but since the facts of cold are as striking as those of heat, it seems proper to speak of them in separate paragraphs. The natural causes of cold are: 1. the absence of the sun, either by night or in the winter; 2. the diminution of the blanket of the atmosphere as high elevations are reached; 3. evaporation; and 4. radiation through a clear air.

Evaporation has been for ages used in the East to cool water for drinking, the evaporation being produced either by putting the water into porous earthen vessels, or setting it on the housetop in shallow pans by night, *the water having been previously boiled.* The Hindoos near Calcutta, by a skillful combination of evaporation and radiation, produce frost artificially. In a high plain they make slight excavations in the ground, and fill them with dry cane stalks, which are non-conductors of heat. Over these they place shallow unglazed pans, which they fill at sunset with cool boiled water. If the night is clear the pans are at sunrise covered with a thin coat of ice, which is collected in baskets and carried to an ice-house to be preserved.

Many salts, on being dissolved, cause the water to expand and fall rapidly in temperature. This effect is sometimes very much increased by using snow or pounded ice instead of water. Thus, muriate of lime or caustic potash, mixed with snow, will sink the thermometer far below zero. The evaporation of liquids more volatile than water will produce a great degree of cold, but a discussion of this and other points relating to cold belongs to a later portion of the work.

Heat is the name both of, 1. a certain primary sensation which can be defined only by its synonym, warmth, etc., and, 2. of the

unknown agency or cause that produces the sensation. All bodies with which we are familiar are under the influence of this agent, its presence being a condition toward fitting the globe on which we are for the habitation of life and intelligence.

Our sensations, as well as observations upon bodies, teach us that heat can exist through a wide range of variation. As a rule, all bodies undergo an increase of expansion while heated, and a corresponding contraction upon cooling. Supposing, now, a convenient substance be found, the expansion of which shall be, through a wide range, exactly proportional to the sensible temperature imparted to it ; it is evident that the observed expansion of such substance will indicate the existing temperature, and show its variations.

In the common method with us of measuring temperatures, a range equal to 1/180 of the variation between the freezing and boiling points of water, as shown by *the expansion of mercury*, is taken as the unit or single degree (1°) of sensible temperature. The succession of degrees of this magnitude constitutes Fahrenheit's scale.

Heat and cold, as known to us, are relatively, not absolutely different ; they are only higher or lower degrees of heat. Increase in length of bodies, due to heat, is termed linear expansion ; and increase in volume, cubical expansion.

Some bodies, it is certain, become permanently elongated by repeated heating ; hence it is that the bars of old fire grates are often found distorted ; and lead pipes conveying hot water have lengthened several inches in a few weeks, being thrown into curves. Glass without lead, and platinum, expand so nearly alike, that they can be soldered or otherwise united in machinery, and exposed to heat or cold without being caused to separate.

Most substances expand, under the influence of heat, more rapidly—some very violently, as in ascending they approach the melting or vaporizing point ; and in descending, they con-

tract correspondingly just before and after condensation or solidification ; in sulphuric acid no such inequality is observed. The force with which bodies expand and contract is enormous, and in practical operations must always be allowed for.

In iron bars or beams abutting against or immovably fixed in walls, there is in consequence generated an immense pulling or pushing force ; this, in a bar no more than ten feet long, has been calculated at not less than fifty tons to the square inch, acting through the distance of the elongation or contraction.

Liquids are more expansible than solids ; but they differ widely among themselves. From 32° to 212°, pure water expands in volume about one part in twenty-two and a half ; fixed oils, one in twelve. Among solids, those of lowest points of fusion, and among liquids, those most volatile, are in the greatest degree expansible. Expansion in liquids caused by heat, occurs with enormous force, but its effect is usually in part compensated by enlargement of the containing vessel ; and because of the latter change, the apparent is usually less than the absolute expansion.

It is by its rapid conduction of heat that a silver or copper vessel receiving a hot liquid is at once too warm to be held in the hands ; while, from want of this property of rapid conduction a glass or earthen vessel can be grasped very near to the portion in contact with boiling water. So, the hand is burned by seizing a metallic rod red-hot at one end ; but not by grasping a wooden rod even nearer to the higher heat of the burning part, thus, all bodies are divisible into the classes of good and poor conductors of heat.

Air saturated with watery vapor has its conducting power increased nearly in a triple ratio—an explanation of the fact that damp air most rapidly robs the body of its heat, and hence feels more cold than dry air. As a partial illustration of the relative conducting powers of bodies in different states, it may be mentioned that a metal burns the hand at 120°, while contact with

a liquid, without motion, may not scald at 150°. The crust of the earth is a poor conductor, first, because mainly composed of oxides, and secondly, because formed in porous and varied strata. Hence it is that, in temperate latitudes, freezing can never extend during the cold months to any great depth.

When in liquids and gases heat is applied at a certain point, the heated parts by rapid expansion become lighter than those about them and rise, and are constantly replaced by those more cold and dense ; so that a circulation of currents of heated fluid upward and colder fluid downward is maintained, until, if that be possible, the whole mass is brought to a common temperature. Hence, it is seen why heat should in such cases be applied below ; and also why anything rendering a liquid viscid, as starch, impedes boiling.

The *heat rays* falling upon any body are disposed of in one of three ways : they pass through it as a medium ; or they enter into its substance and are there arrested, usually producing rise of temperature, an effect known as absorption of the heat ; or they are thrown off or reflected from its surface.

Liquids are kept hot longest in light-colored vessels, as those of silver, and polished ; they cool most rapidly in those that are black and roughened. Pipes designed to keep their heat or to convey it to a distance, there to be given out, require a low radiating capacity ; in the rooms in which the heat is to be dispensed, a higher one, so that here they are impaired by polishing.

Water has a capacity for heat exceeding that of any other solid or liquid ; and as a consequence, the development of a certain sensible temperature in it requires a greater consumption of heat, and hence of fuel, than any other—a conclusion of some moment, when we reflect how vast are the quantities of this liquid that, in the arts, must continually be heated or brought to the boiling state. Again, in cooling through a given number of degrees, the same weight of water gives out heat which, entering

the air and solids, is equivalent to and produces in them a considerably greater sensible heat than that lost by the water. Heat disappears during changes of bodies from the solid to liquid, and from the latter to the aeriform state ; and it reappears from the occurrence of the reverse changes.

The *sources of heat* may, for convenience, be divided into : 1. *mechanical*, as in the case of arrested motion, in blows, friction, etc., and the evolution of specific and latent heat by compression ; 2. *physical*, as that obtained by direct and simple conversion of electricity, or other physical forces ; 3. *chemical*, as that due to oxidation and like changes, 4. *physiological*, or that developed during the vital processes of vegetable and animal bodies—unless, indeed, this division is to be included under the preceding ; 5. *cosmical*, as that due to the radiation of suns, by far the larger part of that by which we are affected coming from the centre of our own system, and also that probably radiating from cooling planetary bodies.

Doubtless, these distinctions do not hold in nature ; heat from all sources is essentially identical, *and it may be regarded as interchangeable with all other forms of force.*

What is heat ?

Heat is a form of energy, represented by the kinetic energy of the molecules of a body.

To what is the temperature of a body due ?

It is proportional to the average kinetic energy of its molecules.

How is heat transferred ?

It is transferred from one body to another by conduction, radiation, and convection.

What is conduction ?

The flow of heat from one part of a body to another. In

some cases it passes more rapidly than in others so we are in the habit of speaking of good and bad conductors. A very poor conductor is called an insulator.

What is radiant heat?

When heat is transferred from one body to a distant one without perceptibly heating the intervening medium. In explanation it is assumed that radiant heat, like light, is of the nature of a wave motion propagated by a hypothetical substance called ether.

What is convection of heat?

This mode of heat transfer takes place when it is changed from one place to another by the bodily moving of the heated substance, as when water is heated in a vessel the hot water in the bottom is constantly rising and the cold water falling to take its place.

What happens if liquids possess a boiling point below the temperature of the atmosphere?

The latent heat of vaporization is drawn from surrounding objects, causing a reduction of temperature, i. e., refrigeration.

What is latent heat?

When a solid passes into a liquid state or a liquid into a gaseous or vapor state, a certain amount of heat is required to bring about the change; it is called the latent heat of fusion in the first case, and the latent heat of evaporation in the latter.

What is the unit of heat and what does it represent?

The British thermal unit, abbreviated B. T. U. is the heat required to raise the temperature of one pound of water one degree F. at the point of maximum density, say 39°. The French and German unit is the amount required to raise one gram of water from 4 to 5° C. That is the small calorie, and a kilogram is the big calorie.

Do writers differ somewhat in their use of the B. T. U.?

There is substantial agreement that it is the amount of heat required to raise the temperature of water one degree Fahr., but some writers employ the term to express the temperature change from 32 to 33, others from 39 to 40, while still others put it from 60 to 61 Fahr.

What are sources of heat?

Friction, percussion, pressure, solar radiation, terrestrial heat, molecular action, change of condition, electricity, chemical combination, and combustion.

What is absolute zero and what does it mean?

About 460° below zero; it means the point where all motion of the molecules ceases. It is theoretical, as that temperature has never been attained practically, and we have strong reason to believe that we should encounter deviations from this law if it were practicable to thoroughly test it.

Is it wrong scientifically to speak of "heat" or "cold"?

It is, technically, the latter being simply a slower movement of the molecules.

How does it resemble light?

It follows the same laws as regards refraction, reflection, polarization, etc.

How are the laws of Boyle and Charles applied to gases?

This theory means that the rectilinear progressive motion of the molecules of a gas represents by its kinetic energy the temperature of the gas, and by the number of impacts of its molecules against the wall of the vessel containing the gas its pressure.

What, according to the law of Charles, is the variation in volume as the temperature increases or decreases?

At 32° F. it increases or decreases 1/493 of its bulk, and it is on this action at that temperature that we estimate, theoreti

cally, the absolute zero at about 460° below zero of the present Fahr. scale.

What is specific heat ?

The number of heat units required to raise the temperature of a body one degree is called its heat capacity.

This heat capacity compared with the heat capacity of an equal weight of water is the specific heat of the body. Hence the figure expressing in B. T. U. the heat capacity of a body expresses also the specific heat of that body.

How does the specific heat of a substance vary ?

It varies with its condition, whether gaseous, liquid or solid. It also changes with the temperature and pressure.

Is the specific heat of water very large ?

It is exceeded by very few bodies.

How do bodies change by variation in temperature ?

As they become hotter they expand, as they cool they contract. That is the general law, but there are some exceptions, as ice, for instance.

What is critical temperature ?

The temperature above which no amount of pressure will liquefy a gas.

What is critical pressure ?

The pressure necessary at or just below the critical temperature to liquefy a gas.

What is the critical volume of a gas ?

Its volume at the critical point, measured with its volume at the freezing point, under the pressure of an atmosphere as unit.

What are critical data ?

The critical temperature, pressure and volume.

How have the relations of pressure, volume and temperature been stated in the form of a law?

By two laws called the law of Boyle and Mariotte, and the law of Charles.

What is the meaning of Thermodynamics?

It is the science which treats of heat in relation to other forms of energy, and more especially the relations between heat and mechanical energy.

What is the first law of Thermodynamics?

It asserts the equivalence of heat and mechanical energy and states their numerical relations, that is that heat and work may be converted into each other at the rate of 778 foot pounds for every unit of heat.

What is the origin of heat energy?

The source of nearly, if not all, forms of energy is the sun. The heat of its rays forms the chemical energy of plants, reappearing later in coal or wood; it also produces the vapors which reappear as water in the form of rain, snow, or waterfalls; its influence on the atmosphere also produces the waters, the winds, and the storms.

How does the molecular theory enable us to understand how heat may be converted into mechanical work?

Supposing the working fluid to be a perfect gas, undergoing no internal changes, we can readily see how the molecules of the gas, under the influence of heat, vigorously bombard the piston in a cylinder pushing it forward; as the piston moves the energy of the molecules grows less and the temperature of the gas falls. If the work done by the piston and the heat lost by the gas were measured in the same kind of units it would be found that they were practically alike.

If there had been no pressure on the piston and it had no weight what would have been the effect ?

It would then have been practically a case of a gas expanding in a vacuum, and while the piston moved, it would have done no work and the temperature of the gas would also have remained unchanged.

Is there any difference between sensible and latent heat ?

This is simply a division that is made for convenience in order to indicate the particular energy change, which is effected within the body. The sensible heat is expended in increasing the velocity of the molecules of a body, while the latent heat is expended in increasing the average distance between the molecules.

Who discovered latent heat and when ?

Dr. Black in 1762.

What is Joule's equivalent ?

The mechanical equivalent of heat; it is called his equivalent because he was the first investigator, although his figures, 772, have been since changed by the results of later investigators to 778 foot pounds.

How may the difference between saturated and superheated steam be expressed ?

The former contains only as much heat as is absolutely necessary for its maintenance as steam at the given pressure, while the latter at the same pressure contains more heat than saturated; in the latter state it approaches the condition of a perfect gas.

In what condition is steam as actually used ?

It is usually moist, that is, it contains a little water.

How is heat produced by combustion for industrial purposes and heating generally ?

By fuels of which the most important are coal. coke, etc.

How is heat generated by chemical combination ?

The resulting compounds possess less energy than the constituent elements before they unite or combine, the difference appearing in the form of heat, electricity, etc. In the same way heat is absorbed during the decomposition of chemical compounds.

What are the maximum temperatures of the combustion of carbon and hydrogen ?

About 5000° F. for the former and 5,800° F. for the latter.

What is an average composition of coal ?

Carbon about 80%, hydrogen 5%, 8% oxygen, 4% ash; sulphur, nitrogen slightly over 1% each.

What is the meaning of diathermal ?

Capacity for transmitting radiant heat ; freely permeable by radiant or reflected heat. Thus, perfectly dry air is *diathermanous*, that is it allows radiant heat to pass through it without being sensibly warmed thereby. Add vapor to this air and its diathermancy is diminished.

Describe the process of distillation ?

It is an operation by which two or more liquids having different boiling points may be separated. It consists of a still in which the mixed liquids are boiled, and a worm coil in which the resulting vapors are cooled and allowed to run into different receptacles.

What is the meaning of the expression, conservation of forces ?

It is the doctrine of *physics*, that energy can be transmitted from one body to another or transformed in its manifestations, but may neither be created nor destroyed. Energy may be

dissipated, that is, converted into a form from which it cannot be recovered, as is the case with the great percentage of heat escaping with the exhaust of a locomotive or the condensing water of a steamship, but the total amount of energy in the universe, it is argued, remains constant and invariable.

What is the meaning of caloric ?

It was a term applied by *Carnot* to the supposed cause of the phenomena of heat, at the period when heat was assumed to be the manifestation of a substance, *caloric*, latent in all bodies.

What is the mechanical theory of heat ?

Energy in the heat form can be transformed into Mechanical Work. The steam engine is a familiar instance of a machine for this purpose. Part of the heat produced by the combustion of the fuel in the furnace passes into the boiler and thence with the steam into the cylinder ; as the steam expands in the cylinder it loses heat, and work is done by the engine.

What is the meaning of entropy ?

Different writers attach different meanings to the word ; it originated with Clausius who employed it to stand for a mathematical abstraction expressing the degree of non-availability of heat energy for the production of mechanical energy under certain conditions. That portion of energy in a system which may be converted into its equivalent of mechanical work is called free energy, and the remainder is called latent energy. Consequently when a transfer of heat takes place in a system without due compensation, the free energy decreases and the latent energy of the system increases correspondingly. Agreeably to this conception the latent energy of a body, divided by the temperature, is the entropy of the body; the increase of the latent energy of a body, divided by the temperature at which it takes place, yields the amount of increase of entropy and vice versa.

What are isentropic changes ?

Adiabatic changes which are reversible, so called because such changes do not alter the entropy.

Can the absolute amount of the entropy be determined ?

Only the changes ; it has been concluded that the entropy of the universe is constantly increasing, tending toward a condition when all energy will be latent.

What is an adiabatic change ?

In the first case, when the gas was allowed to expand while doing work, the maximum of power was obtained when the pressure of the piston was slightly less than that of the gas. If this is done the original condition of the gas can be maintained by making the pressure on the piston only slightly greater than on the gas, when the gas will be compressed to its original volume and temperature.

Both these operations of expansion and compression are adiabatic changes, both are reversible changes, and neither involves any dissipation of heat or energy.

In the first change we have converted heat energy into work, and in the second, work into heat.

What is an isothermal change ?

The expansion of a gas while propelling a piston may be done by replacing the energy expended by the gas on the piston with heat from without. In this case the expanding gas is kept at the same temperature and we say that the expansion proceeds isothermically. This operation may also be reversed, and work converted into heat, by using the power gained by raising the piston to push the piston back, and withdrawing the heat liberated by the work of compression as fast as it appears, so that the gas is always at the same temperature. If during expansion the temperature of the gas is always slightly less and during

compression slightly greater than the outside temperature, both operations are considered reversible, and no dissipation of energy takes place in either case.

What does this allow us to do ?

We may allow a gas to dilute in such a way as to do a certain amount of work at the expense of an equivalent amount of heat, or we may allow it to expand without doing any work; in the latter case it is dissipated, for the gas cannot be brought back to its original condition without the expenditure of outside energy.

What is the principle of frigorific mixtures ?

When a body melts in water or any other liquid, or if two solid bodies (as salt and snow) mix to form a liquid, a certain amount of heat becomes latent, and as it is taken from the mixture itself, the temperature falls correspondingly.

What is the general law governing the production of cold by frigorific mixtures ?

During the liquefaction of a solid a certain amount of heat becomes latent which must be taken from surrounding bodies. The more rapidly or suddenly the solid is liquefied the more marked is the production of cold.

What are the solids used in frigorific mixtures ?

Those of certain alkalies, few others possessing the requisite solubility at low temperatures.

What are some common forms of such mixtures ?

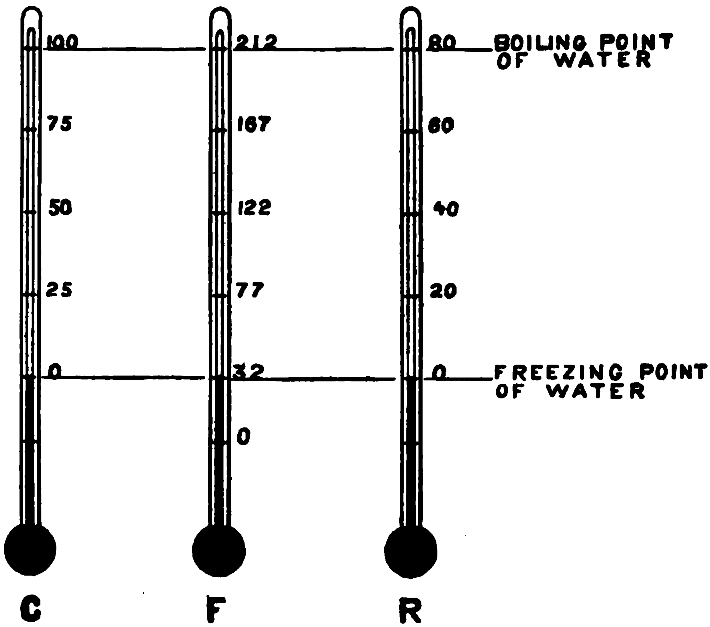
Snow and hydrochloric acid, or snow and potash; also snow and sodium sulphate, ammonium nitrate and nitric acid.

What law governs the liquefaction of gases ?

If the temperature be lowered sufficiently, and proper pressure be applied, all gases may be liquefied.

What is a heat engine and on what does its efficiency depend ?

It is a contrivance for converting heat into mechanical energy; its efficiency depending not on the nature of the working substance but only on the difference in temperature between its entering and leaving the engine.



The above figure shows the freezing and boiling points, respectively, of the Centigrade, Fahrenheit and Reaumur thermometer scales.

What follows as the result of this law ?

It follows as a matter of course that if we desire to convert heat into work by a continuous process we must have besides a working substance a warm body, a source of heat, such as a boiler, generator, etc., and a body of lower temperature into which the heat not available for work in the operation may be

discharged. The latter device is generally called a condenser or refrigerator, and in many heat engines it is the atmosphere.

The same requirements, only in a reversed order, obtain from the continuous conversion of work into heat, i. e., when heat is to be transferred from a colder to a warmer body, the work expended compensating for the transfer.

When quantities of work and heat are used in equations what is always understood?

That they are expressed by the same units.

How is the mechanical equivalent of heat often expressed?

The letter J is used.

What would happen if two vessels containing gases at different pressures should be brought into communication?

The pressures would equalize themselves but no change of heat would take place.

Of what general law is this a branch?

The law which affirms the convertibility of all forms of energy into one another.

To whom are we indebted for investigations of these cycles?

To Carnot, the French physicist.

What law is this in accordance with?

That heat cannot be transferred from a colder to a warmer body.

Why is an air thermometer used?

An air thermometer is used because the expansion of air is more exact than in the case of liquids or solids.

How are gases absorbed?

To a considerable extent by liquids, the amount depending on the nature both of the gas and the liquid; it seems to decrease with the temperature. While a liquid is absorbing a gas a

definite amount of heat is generated, which heat is again absorbed when the gas is driven from the liquor by increase of temperature or decrease of pressure. Solids, especially porous ones, readily absorb gases, as for instance charcoal will absorb ninety times its own volume of ammonia gas, and water will absorb several hundred times its volume of the same gas.

On what fact does the ability of heat to do work depend ?

On its natural tendency to pass from a warmer to a colder body, and therefore, other things being equal, it is directly proportional to the difference of temperature between a warmer and a colder body.

What is a cycle of operations ?

When a working substance returns periodically to its original condition.

On what action is this cycle based ?

Energy cannot be developed from nothing, or the fact that heat cannot pass from a colder to a warmer body.

What are the component parts of heat changes ?

The elevation of the temperature which produces the increase of energy of the molecules; the change produced by overcoming the interior cohesion; the re-arrangement of the molecular constitution of the body; and the change required to do outside work, overcoming pressure.

Is this working medium wholly available theoretically ?

No, because a portion always remains as heat of a lower temperature, and cannot be utilized unless it can be used in passing into a temperature still lower.

What law do we deduce from this ?

The heat energy of a gas is independent of its volume, and the energy of a mixture of gases is equal to the sum of the energy of its constituents.

How does the conversion of heat into work and work into heat take place?

In many ways; generally the change of volume or pressure brought about by heat-changes facilitates the conversion.

What naturally follows as to measurement of heat or work?

That we can measure either in its own or equivalent units.

How is the latent heat of vaporization divided?

Part of it is absorbed while doing the work of disintegrating the molecular structure, while doing internal work as it is termed. The rest of the heat is taken up in doing the work of expansion against the pressure of the atmosphere, and is called the external work. If a liquid be vaporized in a vacuum there is no external work to be overcome, and the first process will take it all.

Do the laws regarding perfect gases vary or show anomalies?

Yes; especially when the gas approaches a state of vapor.

What is free expansion?

When a gas expands against a pressure much less than its own; the refrigeration due to the work done by such expansion may be used to liquefy air as in Linde's method.

Do the usual rules and formulae applicable to perfect gases apply to them when in a state of vapor?

No, there is considerable variation.

What becomes, theoretically, of a perfect gas at absolute zero?

It should shrink to nothing, according to the theory.

What effect has pressure on the melting point?

Substances which expand as they become solid, like water, have their freezing points lowered by pressure, and those which contract have their freezing points raised by pressure.

MECHANICAL REFRIGERATION

AND

ICE MAKING.

The **theory** of an invention or process is well defined, as "the collection of facts and principles that may or may not prove correct upon application"—thus, a machine may be perfect in theory but useless in operation. It is in this sense that much of the preceding matter has been inserted in the very opening pages of the work.

But, the word **idea** might possibly be better used, the word being mental and opposed to anything physical or substantial, hence, the general ideas of refrigeration having been propounded, the everyday application of these principles will now be considered.

What was the first method of mechanical refrigeration to come into use and where?

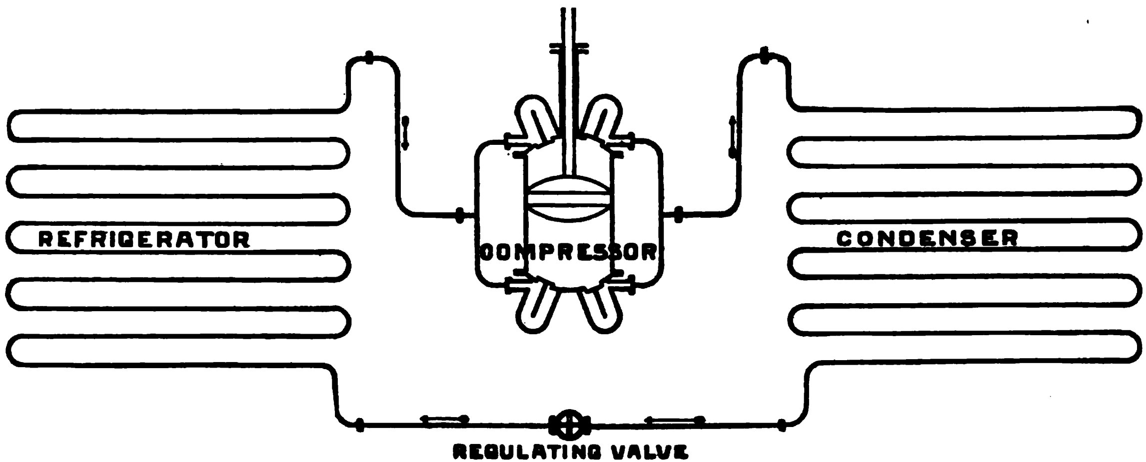
On ocean steamers, by use of cold air, and while this method is still used on them to some extent it has been largely superseded by some form of compression machine using carbon dioxide or ammonia.

What is the principle of operation of ice machinery?

The general principle in all refrigeration machines is the vaporization of a volatile liquid at a temperature below that of the material to be cooled, the latent heat necessary for vaporization being absorbed from the latter.

How does the efficiency of a machine vary?

It may vary considerably according to the local conditions under which it works, that is the work done, the temperature of the atmosphere, and especially the temperature of the cooling water.



This figure illustrates diagrammatically the elementary arrangement of a compression refrigerating plant. The course of the cooling agent is indicated by arrows.

What is the work demanded of a refrigerating machine?

To extract heat from a body and to transfer it to some suitable external agent so that it may be carried away. Water is ordinarily used as this agent not only because it is the cheapest and most readily available, but also because it has a greater capacity for absorbing heat than any known substance. It is simply the abstraction of heat from one body and its transfer to another. If this last stage goes on automatically we have a continuously working machine.

What is the class of machine chiefly used in the United States?

The ammonia machine.

Which ammonia system is most largely in use?

The compression, although the absorption is growing in favor rapidly for meeting certain conditions.

Who brought out the first successful ammonia compression machine?

Prof. C. P. G. Linde, Professor in the University of Munich, Germany.

When was his first machine put up in the United States?

A 25-ton machine in 1880.

How many stages are there in the compression cycle?

Three: compression, condensation, and expansion.

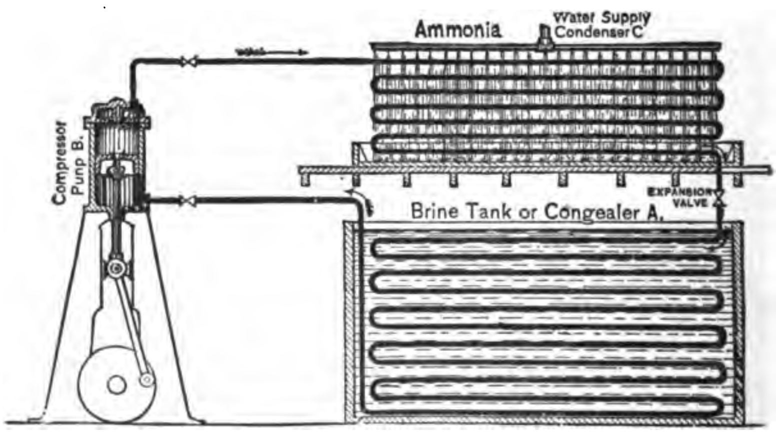
Describe the cycle of operations that is characteristic of all compression machines.

First, the refrigerating or heat-absorbing agent is subjected to pressure, so that when it passes into the second or condensing stage and its temperature is reduced, it becomes liquid.

In this second stage the reduction of temperature is brought about by water which carries away the heat produced by the

compression plus the latent heat set free by the liquefaction of the refrigerating agent.

The third stage is where the liquefied gas is admitted to a series of coils of pipe and suddenly relieved from pressure. It then flashes into a gas and must take up a quantity of heat which becomes latent; the amount being equal to what it has just given up to the cooling water in the condenser.



An outline of a mechanical compression system with vertical compressor. The condenser shown is of the atmospheric type, and the brine circulating system is used, the brine being cooled by the expansion coils in a tank and then circulated through pipes in the refrigerating rooms.

How does the compression machine work ?

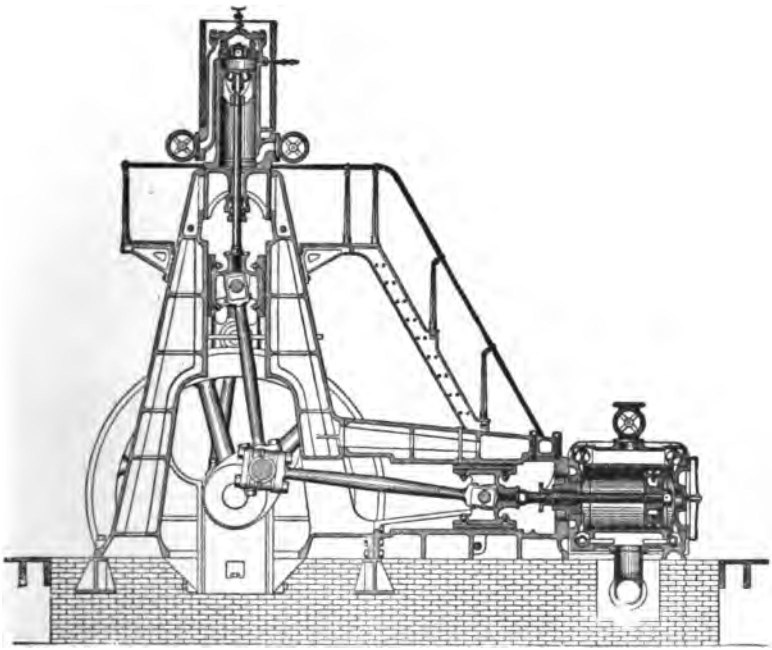
In this type of machine the ammonia vapors, coming from the refrigerating coils, enter a compression pump which forces the vapors into the condenser coils where they are liquefied.

How may motive power be taken ?

The compressor may be operated by a steam engine or by belting from a shaft.

What type of machine is largely used ?

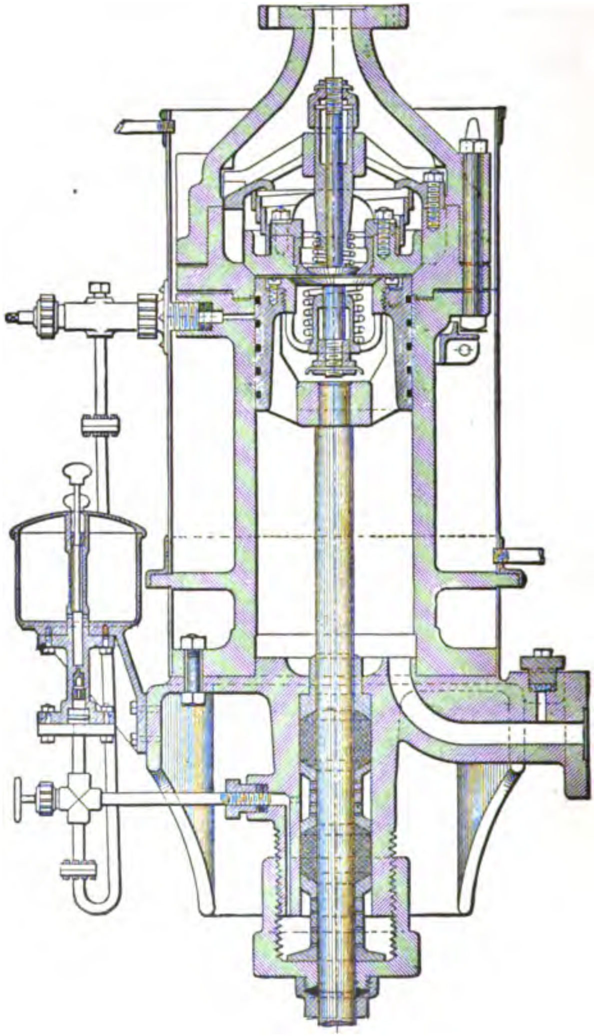
Vertical, single-acting, with false head to the cylinder, and a horizontal engine.



This is a complete vertical section through a single acting compressor with false head. The most approved manner of driving the direct connected compressors is shown in this view. The engine is of the Corliss type and is connected to the same crank pin as the compressor cylinder. In this case there are two compressor cylinders driven by one engine ; the other end of the crank shaft is supplied with a crank which drives the other compressor.

Are horizontal and vertical compressors built to run at different rates of speed ?

The use of the safety head permits the vertical single acting compressor to be run at a higher rate of speed than is practicable with compressors of the horizontal type.



This vertical section of an Eclipse single acting compressor illustrates another type of the safety false head with suction valve piston. The false head is held down by means of one large spring made of flat steel. The entire head is made in the shape of a large valve with beveled seat, the guide of the discharge valve stem forms the stem which keeps the head in a central position with its seat in case it should lift through over-pressure. The discharge valve guide under such conditions is guided by the hub of the spider which holds down the spring for the head.

How are vertical single-acting compressors usually arranged ?

Two are ordinarily placed side by side, with the cranks set opposite, or at 90° to each other, so that one compressor is filling, and one compressing and discharging, at each half revolution of the crank shaft, and the load is thus divided into two units, each of which may be operated singly if desired.

What is necessary to obtain the most effective results in the use of refrigerating machinery ?

A general adaptation of all the parts of the system.

What is necessary to secure the most economical working of a refrigerating or ice making plant ?

The machine should be run at regular speed; and steam pressure, water supply and boiler feed be kept as even as possible. All temperatures should also be uniformly maintained, and the ice should be drawn regularly and systematically, if ice is made.

How is the capacity of an ice machine expressed ?

As a matter of convenience it has become customary to express it in ton capacity, that is by a 100-ton machine we mean the same cooling effect which would be produced by 100 tons of ice melting into water at the same temperature.

Is there any difference between the ice making and the refrigerating capacity of a machine ?

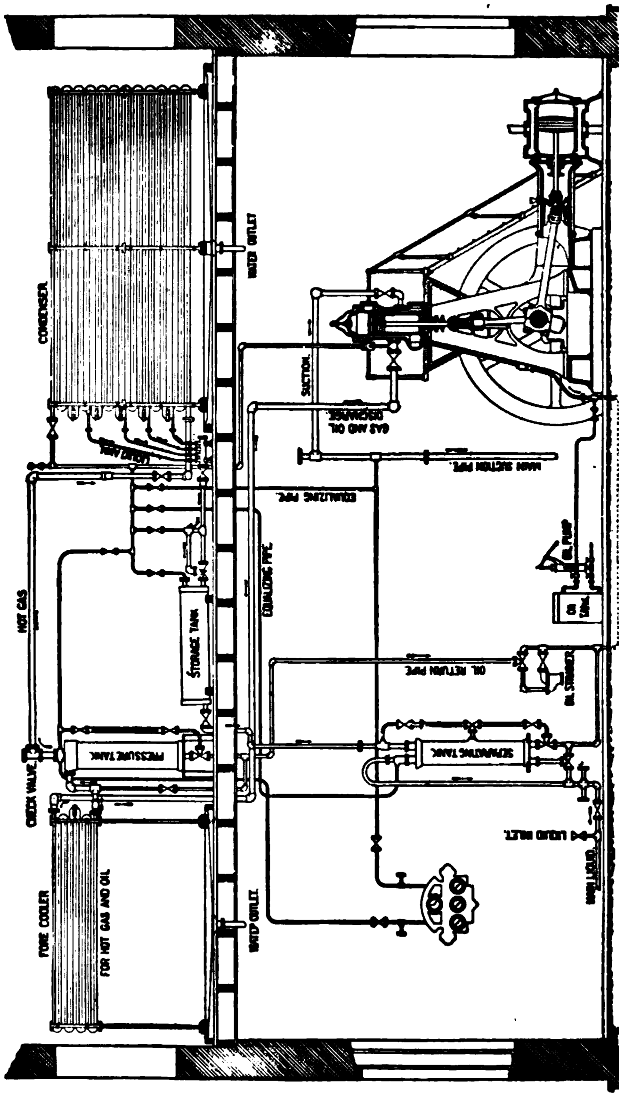
The latter is nearly double the former, the exact ratio depending on the temperature of the water.

How much heat is required to evaporate one pound of water at 212° into steam at atmospheric pressure ?

966 heat units.

What is the equivalent of a ton capacity in heat units ?

In this country, where the short ton is used, 284,000, in Great Britain, where the long ton is still in common use; 318,080.



This diagram illustrates the connection of a De La Vergne vertical compressor for ice making purposes. The vaporized oil contained in the ammonia is condensed in a forecooler and returned to the cylinder.

Give a general description of the compression system.

Take the case of a single acting compressor, and start with the piston at the bottom of its stroke, supposing the upper side of the cylinder to be filled with gas at 15 pounds gauge pressure ; then as the piston rises it compresses the gas, finally discharging it at a gauge pressure of 150 pounds per square inch, more or less, depending on numerous existing conditions. The gas enters the cylinder at about zero temperature, and leaves at a temperature of 220 degrees, very often higher, so that the heat in the large volume of gas has been literally squeezed into a small space and forced through the condenser coils, which are surrounded by running water that absorbs and carries away the heat from the ammonia.

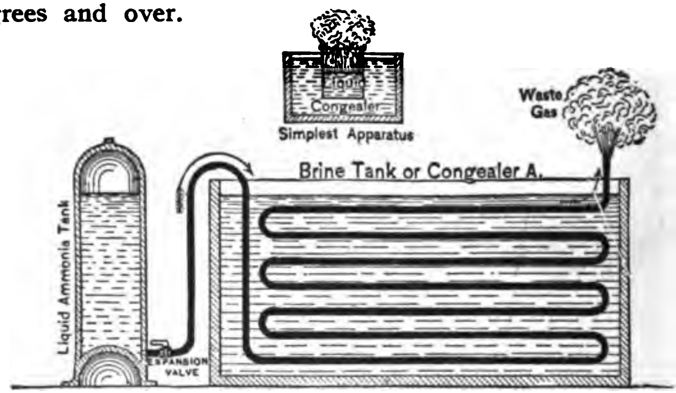
How does the ammonia change to the liquid form and then to the gaseous condition again ?

The ammonia gas is lowered in its temperature to nearly that of the discharge of the condensing water, when it condenses and liquefies under the pressure of the compressor. The liquid ammonia then passes to a receiver and on to the expansion valves, at the brine tank. The expansion valves are needle pointed, and should be fitted with index wheels and levers so that they can be carefully regulated. When the ammonia expands into the expansion coils, the pressure is suddenly reduced from 150 to 15 pounds gauge, and, at the same time, the liquid ammonia becomes a gas, providing there is heat enough within reach to supply the latent heat of the gas ; otherwise, part of the liquid will remain as a vapor. The ammonia absorbs the heat of the brine and is returned through the suction pipes to the compressor, when the same cycle of operations is again repeated.

What does this show the duty of the compressor to be ?

It can thus be seen that the compressor simply acts as a pump to transfer the ammonia from one side of the working

system to the other ; from the low to the high pressure side. At the same time, as already stated, it acts to force the heat out of the gas by compressing it to one-fourth or one-fifth of its original volume. This action can be readily seen in any machine that is running properly, since the suction pipe will be covered with ice and, at the same time, the discharge pipe will be 200 degrees and over.



This illustration shows the manner in which refrigeration is obtained by the evaporation of ammonia. The ammonia tank is connected to the evaporating coil by means of the expansion valve. The liquid through its evaporation takes up heat from the contents of the congealer. Such an arrangement as shown here would not be practical in actual practice as the gas is allowed to go to waste, and in order to use it over again more apparatus than shown here has to be used.

What properties must a liquid possess in order to make it satisfactory as a refrigerating medium?

The most heat is absorbed by substances when changing from the liquid to the gaseous state, or in other words, when they are absorbing their latent heat of vaporization, and for this reason the absorption of heat in vaporization has become the fundamental principle upon which the operation of most refrigerating machines is based. High latent heat would then be one of the desirable characteristics of a refrigerating medium. This is not all, however, for unless it possesses a low boiling point, it would not be useful for cooling purposes.

What are the advantages of ammonia as a refrigerating medium?

It liquefies at a low pressure. It is not explosive or inflammable like ether, and it possesses great heat absorbing power.

Whose names are most closely connected with the compression machine?

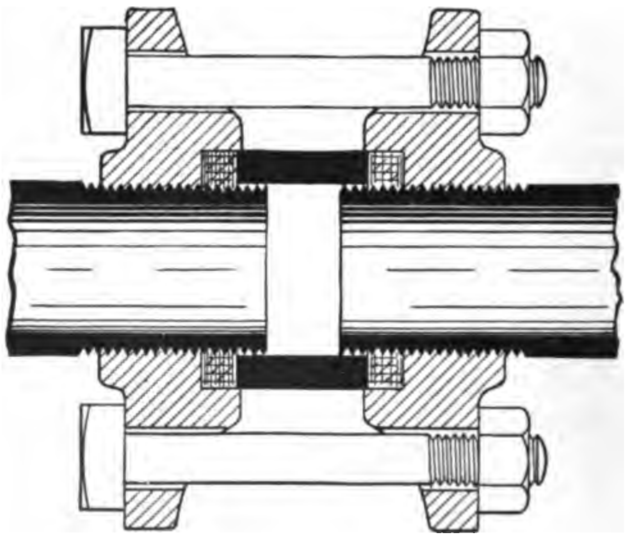
Pictet and Linde. At the close of 1877 and in the beginning of 1878, not only hydrogen, but all the so-called permanent gases were reduced to the liquid state, an achievement the more remarkable as it was the result of the simultaneous but entirely independent labors of two distinguished physicists, M. Cailletet of Chatillon-sur-Seine and M. Pictet of Geneva. The experiments of the former demonstrated the possibility of liquefying carbonic oxide, hydrogen, marsh gas, nitrous oxide, nitrogen, and oxygen; those of M. Pictet oxygen and hydrogen. Pictet thus succeeded in liquefying and solidifying hydrogen on January 10th, 1878, Cailletet having demonstrated its liquefaction on December 30th previously. It is to be remembered that while Cailletet was the first to liquefy the so-called permanent gases, that Raoul Pictet and Prof. C. P. G. Linde were leaders in utilizing these discoveries in the development of a commercial working machine.

How are compressors built?

Ammonia compressors are built in vertical and horizontal types, and single and double acting in both patterns. The horizontal compressor is more easily handled and cared for than the vertical type, while the vertical machine has the advantage of more uniform piston and guide wear. The double-acting machine has twice the capacity of the single, for a given floor space, but is a harder machine to keep tight about the piston-rod, owing to the high pressure of the compression and to the extreme range of temperatures between the suction and the compression pressures.

What is the power required to operate a compression machine to produce a ton of refrigeration ?

Very large machines may be operated with one horse power per ton of refrigeration in 24 hours, but machines of from 10 to 40-ton capacity will require from 1½ to 2 horse power, and it may run up to 3 for small machines.



One of the approved forms of ammonia joints is here shown. It will be seen that in addition to the screwed connection a gland with soft packing is used, which enables the engineer to tighten up on the joint without disconnecting it.

What liquids are or have been used for refrigerating purposes ?

Ether and sulphurous acid were used in the development of the refrigerating machine but they have been practically superseded by the use of carbon dioxide in marine service, and to a still greater extent on shore by aqua and anhydrous ammonia.

AMMONIA
COMPRESSION SYSTEM.

It does not take a very large boulder to keep a powerful locomotive from starting : in fact a very slight obstacle will effect that result. It does not take a whole bag of sand to blind a person : in fact a single grain in the eye will do it.

So in common life, an explanation at the beginning of a study, which does not explain, but on the contrary, by the use of words without sense, rather conceals knowledge, may prevent for all time an access to the higher planes of the study.

Hence, it is well, even at this stage, to define and still further explain the three words at the beginning of this chapter.

Ammonia has been spoken of on page 35 and it fills so much space in other parts of the book that no excuse exists for any one saying he does not know what ammonia is or its relations to refrigeration.

The second word—*Compression*, may be thus thought of : It comes from the latin **compress,** to press together ; to force, urge or drive into a narrower compass ; to crowd ; to squeeze with great force. The word bristles with the sense of energetic action in driving a compressionable substance into smaller volume ; in this case, ammonia gas into a smaller compass. Ammonia compression simply means the squeezing together of the gas which, when compressed makes anhydrous ammonia.

System—as a descriptive word indicates the union of many facts, processes and operations into an orderly and consistent whole. System embraces not merely a law of action or procedure, but a comprehensive plan in which all the parts are related to each other, as in this chapter—a combination of various forces working together for the production of cold air or ice.

There are various systems working more or less successfully, for ammonia is not the only substance that can be used for this purpose. Carbon dioxide liquid has a boiling point much below that of ammonia, but its heat of vaporization is less per pound of the material. Ordinary gasoline or naphtha could be used for refrigerating purposes. Thus, a barrel of gasoline left exposed in the air will spontaneously evaporate, and, if the day is sufficiently cold, can almost be made to boil. This evaporation produces refrigeration by the absorption of the latent heat of vaporization of the gasoline from the liquid itself.

Any volatile liquid, if its boiling point is below that of surrounding bodies at the pressure of the atmosphere, can produce refrigeration. A barrel of ammonia if allowed to evaporate in a room would cover itself completely with ice from the moisture in the atmosphere.

Now, if liquid ammonia was a common and cheap commodity, we would need no machinery to produce refrigeration. All the machinery required in a refrigerating plant is to save the ammonia gas and reconvert it into a liquid for use again. Thus the machinery is not refrigerating machinery in the strictest sense; it is simply a liquid producing machine.

Since ammonia is expensive, we must save it and use it over again. This is the reason for the machinery; it has nothing to do with the refrigeration.

A liquid must be selected which has a high latent heat of evaporation. Ammonia gas compressed and condensed into a liquid is found to satisfy these requirements better than any other substance.

How may refrigerator machines be classified ?

All ice machines which have proved of practical utility may be grouped under two great classes : those which utilize the lowering of temperature that accompanies the rapid expansion of a compressed gas, and those which make use of the like thermal effect that results from the volatilization of some liquid.

In machines of the first type, the gas employed is usually atmospheric air which is first compressed by a pressure of three or four atmospheres, and then cooled in an inter-cooler by circulating water. The air is then expanded in an expansion cylinder where a large portion of its heat is turned into work.

The temperature of the air is now reduced to about fifty or sixty degrees below zero, and it is ready to be discharged either into the room that is to be cooled or into piping for the purpose of cooling brine.

The above cut is a perspective view of a tee as used in ammonia piping. The flange which matches the fitting is screwed on the pipe, and a washer of soft rubber is compressed by the lip on the fitting.

How may the second group be still further divided ?

Among machines of the second group there is a great variety of construction, because of the great differences which exist in the properties of the liquids used. Thus water, sulphuric ether, bisulphide of carbon, ammonia, methylic ether, and other substances have been employed as refrigerating agents. In all

cases of the second group it is the so-called latent heat of vaporization that is utilized ; and did the efficiency of the method depend only on this, water would undoubtedly be the best material on account of the great latent heat of its vapor. But as important from a practical point of view are the vapor pressures that come into play throughout the range of temperature employed.

The above fitting is an elbow for ammonia piping, in this case the flange is provided with four bolts.

Are refrigeration machines necessarily employed in ice making ?

Machines which are capable of freezing water may, in certain circumstances, be much more efficiently employed to produce cooling without freezing. For instance, in packing houses, breweries, sugar refineries, provision stores in hot climates, and in ships engaged in the transport of meat, where it is of importance to have the temperature moderately cool, it is usually by no means necessary to obtain ice. In many such cases, indeed, the production of ice would be a mere waste of power. In tropical and sub-tropical climates refrigeration is of high importance from a sanitary point of view.

What are the different forms of compressors ?

The high temperature reached by the gas during compression makes it necessary to provide some means for keeping the cylinder and valves cool. The different methods of doing this have led to the following types of compressors : First, the dry system ; second, the wet system. In the dry system, the outside of the cylinder is water-jacketed, and a constant stream of water is kept flowing through the jacket to carry off the heat from the cylinder and valves. The advantage of this system is that it does not introduce oil into the pipes to get in the expansion valves and freeze or clog them up, nor to coat the inside of the pipes and reduce the efficiency of the plant. The disadvantage is that, as a matter of fact, in large machines, the cylinder walls will become very hot, which causes the ammonia to dissociate.

How is the second system further divided ?

The second system is again divided into two classes, namely, where oil is forced into the cylinder, the object being to fill the clearance spaces and to lubricate and cool the cylinder, and where a small amount of liquid ammonia is injected into the cylinder for cooling purposes. The worst feature of the oil system is that the oil gets through the whole system and is apt to cause trouble, as well as to decrease the efficiency of the plant. The oil has to be a special mineral oil of zero chill and 400 degrees flash point.

Why is the use of oil troublesome in compression plants ?

The difficulty comes in separating oil from the gas in the separating tanks.

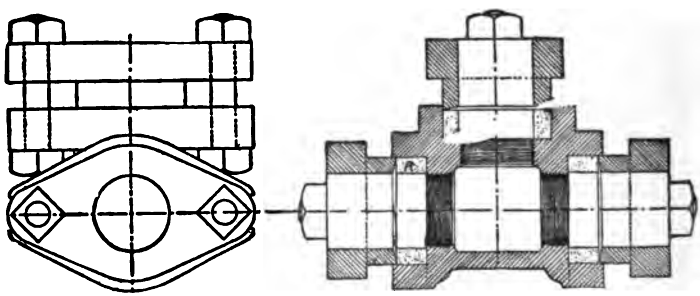
The rapidity with which the gas and oil flow through the tanks is similar to a miniature hurricane, and renders the oil separation which is usually accomplished by gravity practically impossible.

What is the natural result of this ?

The oil flows rapidly to the condenser and back to the liquid tank where it must be drawn out from the liquid. The oil coolers become gas condensers, there being no oil in the separating tank to fill them.

The gas liquefying in the oil cooler flows back to the oil valves, entering the compressors, and as there is no oil for sealing the piston rod the gas flows down the rod past the packing and soon filling the engine.

All this is the result of an overload on refrigerating machinery of the ammonia type, using oil for sealing of valves and rods and filling clearance space.



The above sectional cut shows another type of ammonia fitting. In this case the pipe is screwed into the fitting. An annular space is formed around the pipe by means of a counterbore, into which soft rubber packing is compressed by a gland, and thus all chance of leakage is eliminated.

What form of compression machine is one of the most favored in this country ?

The single acting, false head.

What is the principal object of the false head ?

To avoid liability of damage to the compressor in case any liquid or solid matter should enter it.

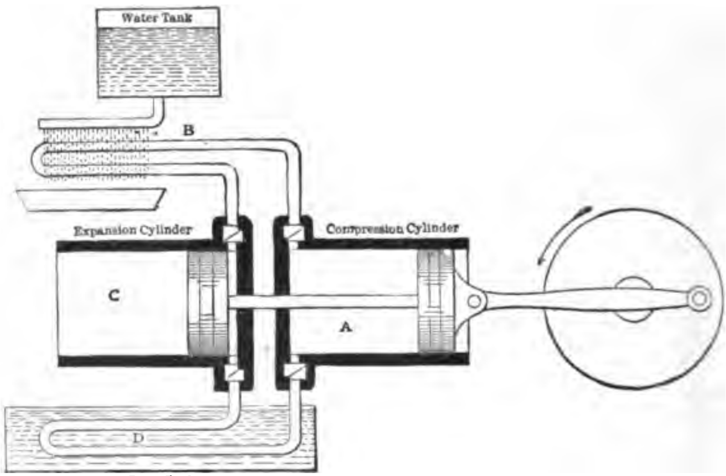
Explain the diagram of an air machine?

The drawing on page 78 is an elementary refrigerating machine, such as would be required to carry out a theoretically perfect cycle of operations. The air is compressed in the compression cylinder "A," after which it passes to the inter-cooler "B," where it is relieved of a large per cent. of its heat. From the inter-cooler the gas passes on to the expansion cylinder "C," where it loses more heat because of the work which it does in expanding behind the piston. The work done by the gas expanding is recovered in that it is made to assist in compressing the gas in cylinder "A."

What takes the place of the expansion cylinder in most systems?

In practical refrigerating systems, in which the working medium is carried through the liquid state in order to make use of the large latent heat of liquefaction which most substances possess, the expansion cylinder is omitted and a valve, which serves to regulate the flow of the liquid from the high-pressure, or condenser, side to the low-pressure, or cooler side, where it is evaporated, is used instead. This valve and the low-pressure coil of the pipe, in taking the place of an expansion cylinder, inherit the name of expansion valve and coil.

The liquid line may be connected to the bottom at the expansion coil to give what is known as bottom expansion; or the liquid lines may all be connected to the top of the coils to give what is known as top expansion. Authorities differ widely regarding which of these two methods is the better. If the coils are very short and so arranged that they will drain themselves, and are placed in rooms of such a low temperature that the heat exchange and the evaporation of the liquid will be comparatively slow, top expansion would be quite likely to give trouble by allowing too much liquid to be carried, or run back into the gas header, and thence back to the machine.



The above illustrates an elementary compression plant employing an expansion cylinder instead of an expansion valve. In actual practice where a liquid refrigerant is used the expansion cylinder is omitted, but it is indispensable in a compressed air refrigerating system.

What conditions make top expansion desirable and what bottom ?

Where long coils are employed, and it is not necessary to force them, top expansion is often considered preferable. Obviously, in either case, if liquid is fed into the coils ever so little faster than it evaporates, there will be an ultimate flooding of the coils, and subsequent freezing back to the machine. Bottom expansion, however, allows more liquid to collect before freezing back occurs, and consequently gives the man who regulates the expansion valves more opportunity to get them properly adjusted before the liquid comes back to the machine.

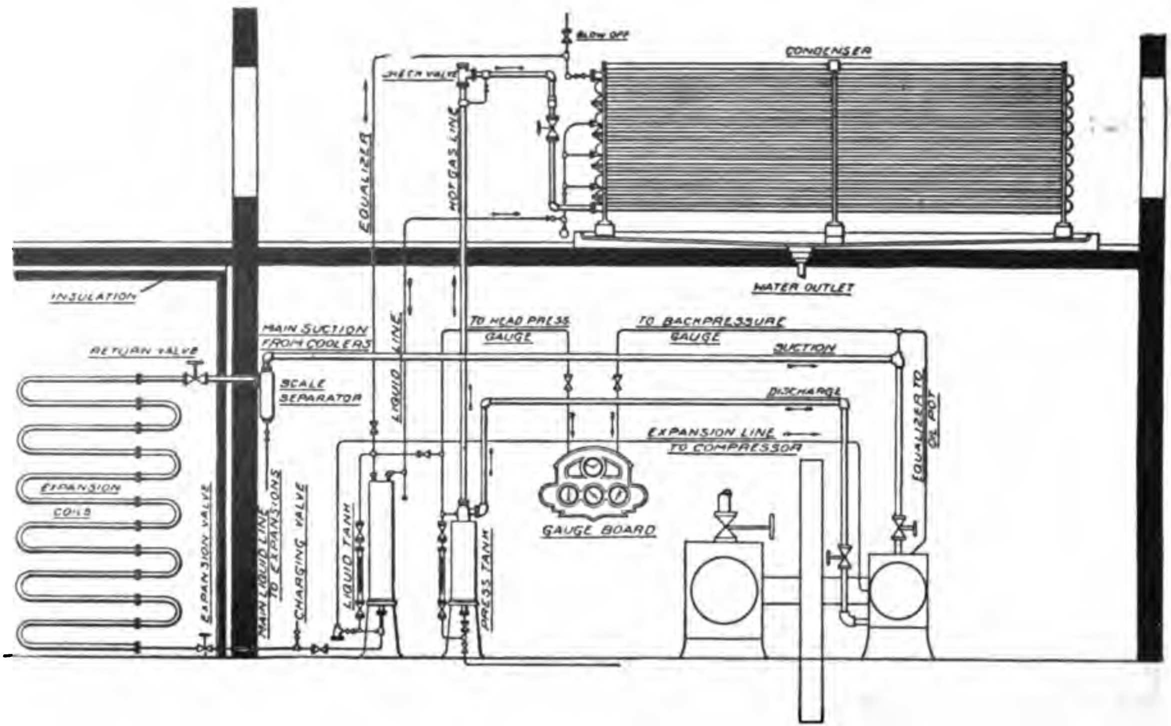
As far as the effectiveness of the two methods is concerned, there is little difference when the coils are of usual length and run under average conditions in which frost is carried the full length of the pipes.

What law controls the velocity of heat flow ?

The velocity of heat flow depends upon the difference in temperature tending to produce that flow, just as velocity of flow of water depends upon the difference in pressure tending to produce that flow. Now, at a given back pressure the temperature of saturated ammonia vapors is always the same, so that the temperature within the coil must be the same throughout its entire length, as long as a sufficient amount of liquid is being evaporated to keep the gas saturated. With the same temperatures within the coil through its entire length, and the same temperature outside of the coil, the rate of heat transfer, on which the efficiency of the coil depends, must always be the same.

How does top and bottom expansion work in practice ?

With bottom expansion, where the tendency is for the liquid to remain in the lower pipes, it may be possible for the vapor to become superheated after it has traveled some distance up the coil. In this case a higher temperature will exist inside of



This view illustrates a De La Vergne plant with horizontal compressor. It will be noticed that the gas enters the condenser at the bottom. The condenser is of the atmospheric type, and thus the counter-current effect is obtained. The liquid in such cases is drawn off at different levels.

a part of the coil, and, there being a smaller difference in temperature to produce a flow of heat from the atmosphere surrounding the coils to the refrigerating medium within, the efficiency of the coil will be somewhat impaired. In top expansion the liquid is usually strung out the entire length of the coil, so that the saturated condition first described is more likely to be found throughout the full length of the coil.

Where is the scale separator and why is it necessary ?

Leaving the expansion coils through the separate return valves, the ammonia gas enters the main return, or suction leader, which, after entering the engine rooms, joins on a scale separator that removes any foreign matter that might otherwise enter and damage the compressor. There is always sure to be more or less scale from the pipe bends, which cannot be gotten rid of by any amount of blowing out with air, and it is likely to come floating along down the suction line when it is least expected.

What is the first process in pumping out the expansion coils ?

If you wish to pump out one of the expansion coils, the first thing to do is to shut off your main liquid line valve and run the machine until the pressure comes down to atmospheric, just as though you were going to shut down. If the pressure does not rise too rapidly again, showing that there is unevaporated liquid ammonia in the expansion side of the house, you can either shut off all of the return valves, except the one on the coil to be pumped out, and then pump that one coil down to the lowest vacuum you can get and then disconnect it, or, in case there are no coils on the low-pressure or expansion side that are liable to have water pulled into them by the vacuum, through any slight leaks there may be, as might readily happen in case of expansion piping submerged in brine tanks, you can go ahead and pump the whole low-pressure side down to a vacuum.

Where must leaks be looked for ?

You are not supposed to have any leaks ; but where the pipe is covered up in a brine tank there is more chance that there may be some little ones giving up ammonia than where the coils are in a closed room, where it will quickly be detected. Then, again, if you do get a little air into the system it is not so hard to get rid of as water is. When you get the coil pumped out, so that it will stay pumped out, you can go ahead and disconnect it.

Why may ammonia sometimes remain unsuspected in coils?

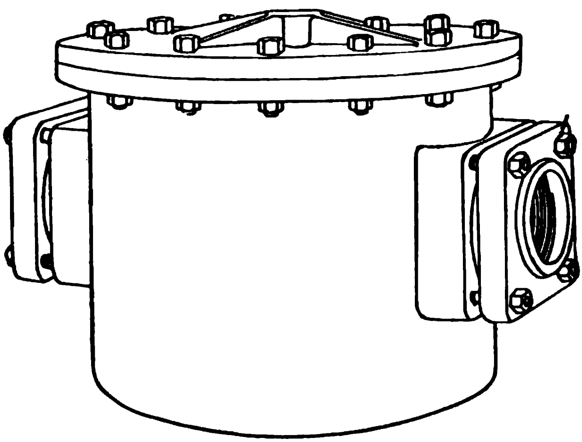
Sometimes a coil may contain quite a large amount of liquid ammonia, in which case the fact that the low-pressure gauge indicates a vacuum does not necessarily mean that there is no longer ammonia in the coil. This condition is accounted for as follows : It is often the case that, at the higher back pressure, due to warmer rooms, the liquid fed into the expansion coils of other colder rooms evaporates very slowly, or, if the back pressure be high enough and the rooms cold enough it will not evaporate at all.

Now, when the back pressure is removed, the liquid commences to evaporate and continues to so long as it can get the necessary heat to convert it into a vapor. Being in a cold room, there is little available heat, however, besides that due to its own temperature, and an evaporation of a very small amount of liquid is sufficient to exhaust this heat and reduce its temperature to such a low point that it cannot boil or evaporate.

Why does this often lead to serious trouble ?

This condition of affairs has often given rise to serious accidents where the workmen, thinking that because there was no pressure indicated on the back-pressure gauge, there was no liquid in the coil, have disconnected the piping and met with a flood of liquid. It is always safe to wait a few minutes after pumping down the system to see if the pressure is going to

return. Of course, if there is thought to be any liquid in the coil in question, its evaporation may be hastened by the application of heat, either from some outside source or by simply removing the ice on the coil, so that it may more readily take up heat from the air. A few inches of exposed pipe furnishes the best means of judging what is going on within it. For example, if the pipe is scraped perfectly clean of frost, and any ammonia is being evaporated within it, the bare surface will be again quickly covered with crisp white crystals, and if the finger tips are moistened and placed in contact with it the temperature can be judged to some extent by the way they "stick," or freeze to the frosting pipe.



This ammonia strainer is placed in the suction pipe of the compressor; it will intercept any scale or deposit that might injure the compressor.

Where does the gas enter a compressor of the vertical single acting false head type ?

The gas enters at the bottom of the cylinder during the up stroke of the piston and passes through the suction valve in the piston during its down stroke.

In what respects are the ammonia compression and absorption machines similar?

The condenser, liquid receiver, expansion coils, brine tank, brine pump, and freezing tank; the expansion and other valves, pressure gauges, thermometers, etc., are also the same.

Where do compression systems mainly vary?

The most important difference is usually in the compressor.

How do compressors differ?

They may be vertical or horizontal, and single or double acting, besides much variation in the details of the valves.

Where is the compression done in vertical cylinders?

In the upper part.

What has led to the diversity of compressor design?

Clearance and cylinder heating are responsible for the many variations in ammonia compressor design and operation.

What is the refrigerating capacity of a compressor?

The refrigerating capacity of a compressor depends upon the number of pounds of gas it will handle in a given unit of time. The weight of ammonia gas handled depends upon the efficiency of the compressor and upon the suction pressure, or the pressure at which the gas is delivered into the compressor.

Give an example explaining this.

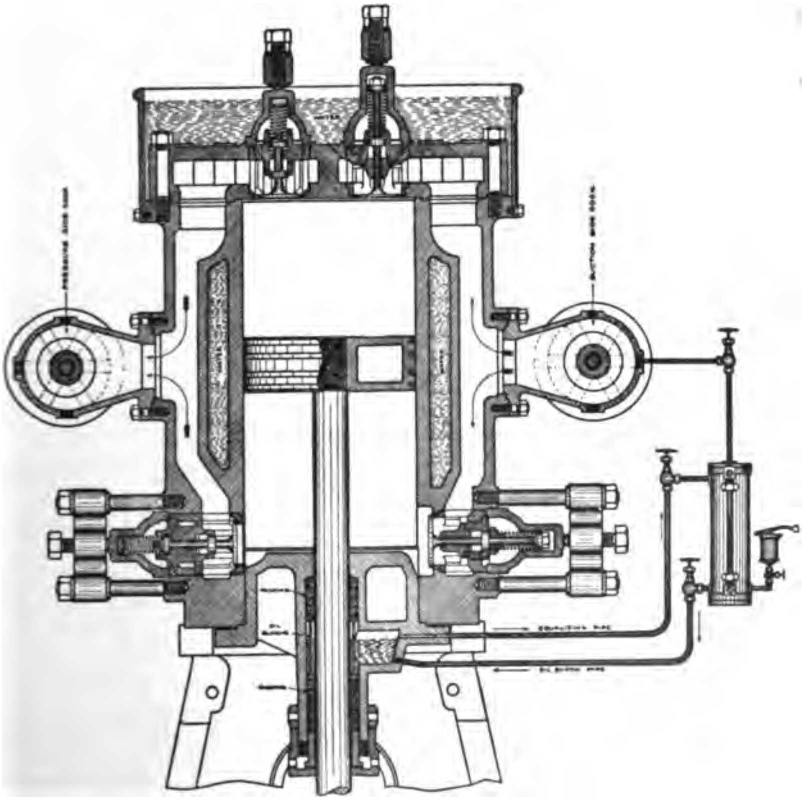
Since the weight of ammonia gas varies approximately as the absolute pressure, it follows that the refrigerating capacity of a compressor varies with the absolute suction (or back) pressure; thus, a compressor working under a suction pressure of 30 pounds (gauge pressure) will have approximately 50 per cent. greater capacity than one working under 15 pounds gauge pressure.

What is the ideal sought in the compressor?

To pump the greatest amount of gas at the lowest cost.

What is the false or safety compressor head, and why is it used.

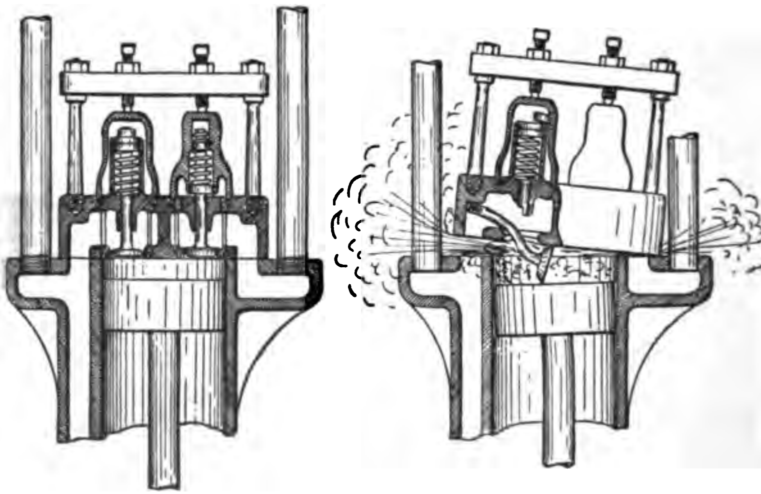
In order to make it perfectly safe to work the piston **metal to metal** against the top cylinder head, the pump head is made



This illustration is a vertical section through the cylinder of the Buffalo compressor, which is of the vertical double acting type. The suction valve stems are provided with a safety collar which is forged solid with the stem, and which prevents the valve from dropping into the cylinder in case the nut should become lose. The lower guide of the stem is made in halves so they can be slipped on the stem between the collar and the valve disk.

The stuffing box oiling device is connected to the suction pipe as shown, thus the pressure is always equalized with the low side of the system and any gas leaking by the packing into the oil well will escape into the suction of the compressor.

movable, in other words, it is simply a large valve, the full size of bore of pump, through the seat of which the piston may pass without injury, raising the head before it sufficiently, in case of any part getting loose, that no damage may ensue, such as knocking out a cylinder head.



In the above drawing an accident has happened to one of the old style vertical compressors without safety head or safety attachments on suction valves. The suction valve spring cap and nut have unscrewed, allowing the valve to drop into the cylinder, and, being caught in the return stroke of the piston, have burst off the pump head as shown.

What is necessary in the springs of compressor valves ?

They should be carefully adjusted, for a great lossof efficiency is experienced if the spring of either suction or discharge is too strong.

What is the best method of adjusting these springs ?

By using an indicator. In fact it is very difficult to obtain proper adjustment without its use.

What are the most important difficulties in compression ?

To give a perfect discharge of gas from the pump, and to avoid leaks in the stuffing box.

How is the clearance largely overcome ?

By bringing the piston close up to the head which is held in place by a spring.

Can the clearance be entirely done away with ?

In practice it has been found impossible to construct machines without it, and it is simply a question how to reduce it to a minimum and so arrange it that the loss may be as slight as possible.

What plan of construction has been found to be most satisfactory ?

A small bore cylinder and long stroke, for the greater the ratio between the diameter and the stroke the less the loss of efficiency.

What is regarded as the best ratio ?

A stroke of three times the diameter.

What beside cylinder clearance must be avoided ?

That there is no unnecessary clearance left at the inlet and discharge valves.

What is one of the oldest compression systems in use in this country and what is its characteristic feature ?

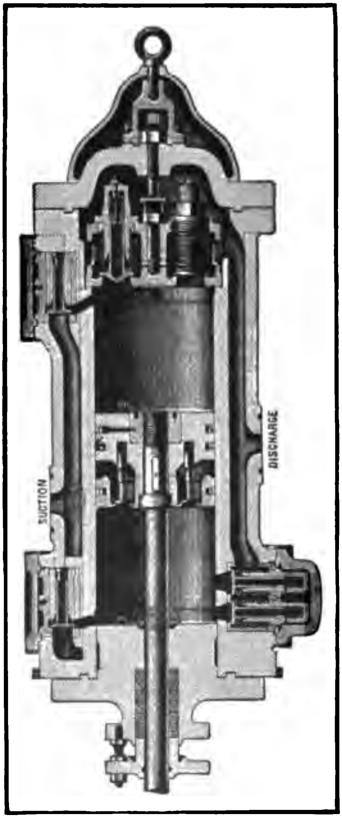
The De La Vergne which uses oil in the cylinder, first to fill the clearance space, and second, to absorb the heat of compression. Oil is also used in the stuffing box.

Is this method of sealing thoroughly satisfactory ?

No, because the oil absorbs the ammonia gas under the pressure of compression and gives it out again during the suction period.

What are the parts that are sealed by oil in the De La Vergne machine ?

The clearance space, the suction valve, the discharge valve, the piston, the piston valve, and the stuffing box.



This figure illustrates the cylinder of a De La Vergne vertical compressor. The oil for filling the clearance space is shown at the bottom of the cylinder and on top of the piston. At the end of the discharge stroke this oil is forced into the ports of the suction valves, thus reducing the clearance. It will be noticed that the bottom end of the cylinder is provided with two discharge valves, one above the other. This is done to reduce the clearance space to a minimum by allowing the piston to come very close to the cylinder head. When the port of the lower valve is closed by the piston, the remaining gas passes through the ports in the piston and the upper valve.

Does the De La Vergne Co. make any difference in construction between vertical and horizontal machines?

Oil is used only in vertical machines.

What quality of oil should be used in the compressor?

Only a mineral oil that will withstand a low temperature.

Does the use of oil in the compressor answer any purpose other than sealing the clearance?

The oil further tends to alleviate the high temperature effects of the cylinder walls, since it absorbs a portion of the heat of compression, the object of the system being especially to produce what is equivalent to a water jacket in the interior of the cylinder as well as on the exterior.

Is this method wholly successful?

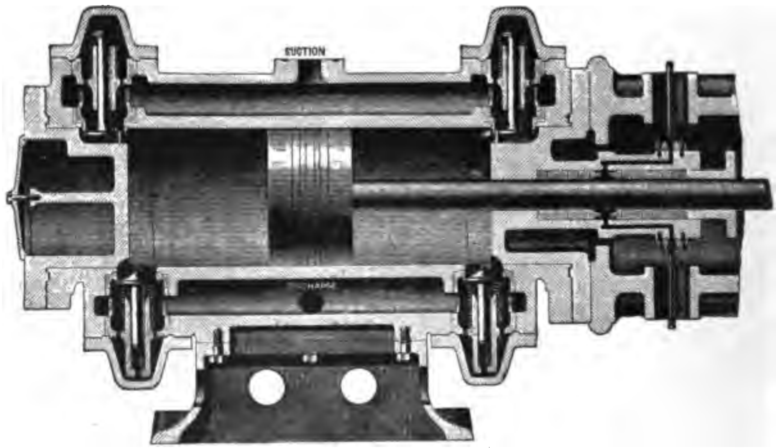
While it possesses advantages the oil under high pressure takes up a large quantity of gas which is released on the return stroke; on the other hand the oil serves to seal the stuffing box, valves and piston, and takes up more or less of the heat of compression.

What is the objection to oil in a compression system?

The serious difficulty incident to the operation of an oil circulating system in conjunction with the compressor is the fact that the oil cannot be kept in this part of the system alone. In practice a large quantity of oil, sometimes approximating a barrel of oil and ammonia, can be taken from the ammonia cooler each month, that represents oil which has gone over through the condensers and cooling coils and whose general action is to diminish greatly the effect of the cooling coils. Hence, it can be assumed that this type of compressor requires a somewhat larger ammonia condenser and evaporating system than is required with the simple machine.

Why is oil quite effective in absorbing the heat of compression ?

Because the action is direct and the heat does not have to act through the walls of the cylinder on water in a jacket.



This cut of a De La Vergne horizontal compressor shows the absence of oil in this type ; the construction of the valves and the lubrication of the piston rod is also illustrated.

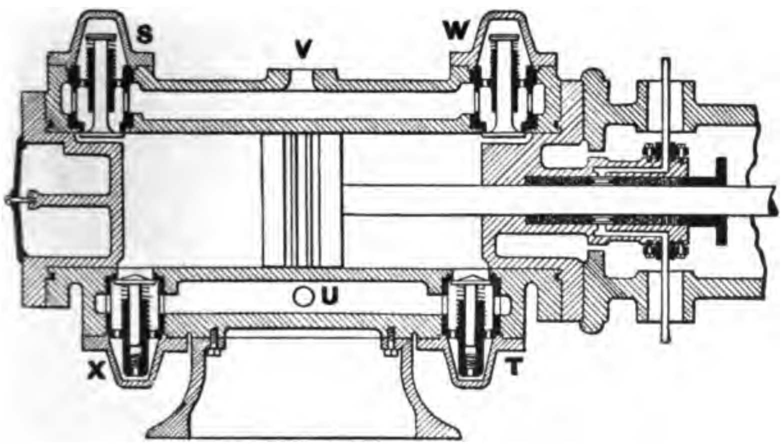
How does the quality of the oil seriously affect the working of the machine ?

The oil itself, unless of a very high grade, absorbs a large amount of ammonia gas under pressure and gives this up with decrease in pressure and rise in temperature, very much as the absorption machine operates in the evolution of ammonia gas from aqua ammonia. Oil is in reality a sponge for ammonia, so that the clearance effect is not completely eliminated and there exist alternate expansions and compressions of the volume of gas given off from this oil.

Explain the action of a double action horizontal compressor ?

Let us imagine that the piston is moving toward the left hand, then whatever substance is being used as the refrig-

erant is compressed and discharged through the eduction valve "X" and out at "U." At the same time the refrigerant, after doing its work by absorbing heat from various sources, is drawn into the compressor through the induction valve "W." Now assume that the piston has reached the end of its stroke



In the above figure is shown an outline of a De La Vergne horizontal compressor. V is the suction inlet, S and W are the suction valves; the discharge valves X and T are at the bottom of the compressor, thus allowing all liquid or oil to pass out with the gas through the discharge connection U.

and has discharged all, or nearly all, of the compressed gas. The piston will then reverse and move toward the right; the gas that was drawn in through "W" will be compressed and discharged through "T," and during this stroke toward the right, more of the refrigerant gas is drawn in through the induction valve "S," which gas will be compressed and discharged through "X," as in the previous stroke. The compressor is thus made double-acting by the use of four valves, one induction and one eduction valve being placed on each end of the cylinder.

How do these four valves work ?

As will be noticed, when valve "X" is open, valve "W" is open, and in a like manner when valve "T" is open, valve "S" is also open ; that is, the valves on opposite corners are either open or closed at the same time. The eduction valves are fitted with heavy springs and the induction valves are equipped with light springs. The heavy springs should not be strong enough to permit the pressure in the compressor to rise above the condenser pressure, and the light springs should not be heavy enough to permit the back pressure in the cylinder to fall below the suction pressure maintained in the suction line.

Should a compressor be run at slow speed ?

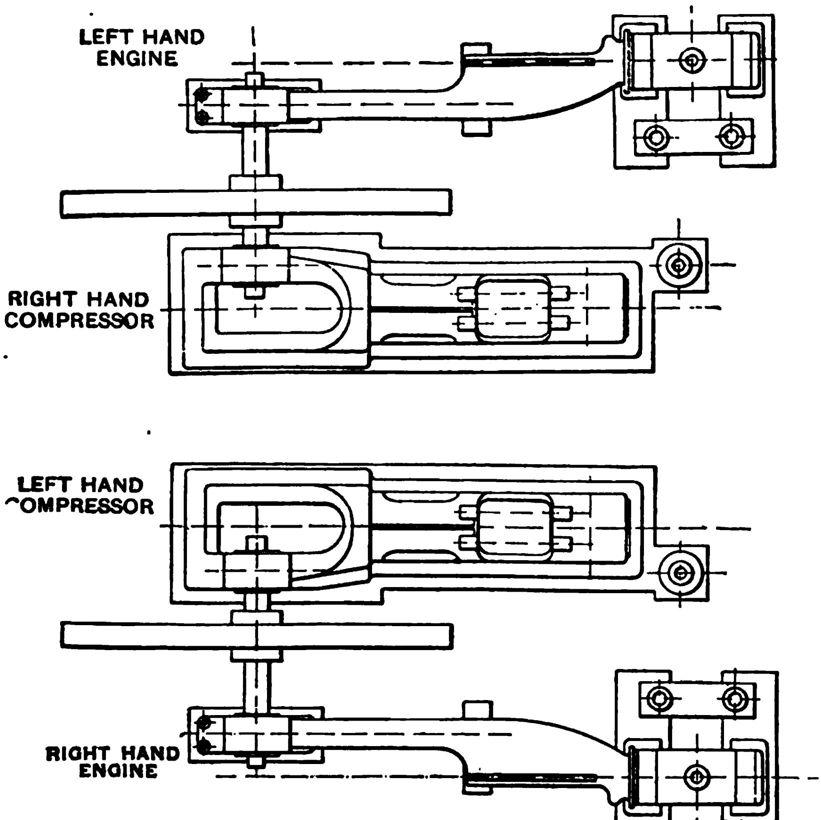
The approved practice in modern steam engineering, and the best results, are obtained at a fair piston speed and moderately quick rotation, and compressors are **handling a perfectly elastic gas,** which will respond and fill a properly constructed pump, fitted with proper valves, faster than there is any occasion to run a compressor. Really there is no limitation, except a structural one, restricting the adoption of any required speed to secure the highest duty. All that is needed is a properly designed machine, which is perfectly **adapted** to the speed selected, and practice proves that there is no more wear and tear on this than on a slow-speed machine or a first-class steam engine ; it is simply a question of properly proportioned parts. The limit of speed is the action of the pump valves, on a properly designed machine.

Is it necessary to open the compressor or its valves to learn their operation ?

The engineer should be able to tell whether they are working properly by putting his hand on the inlet or outlet pipes. Conditions in regard to both compressors of a pair should be exactly the same, any difference indicating that something is wrong in their operating conditions.

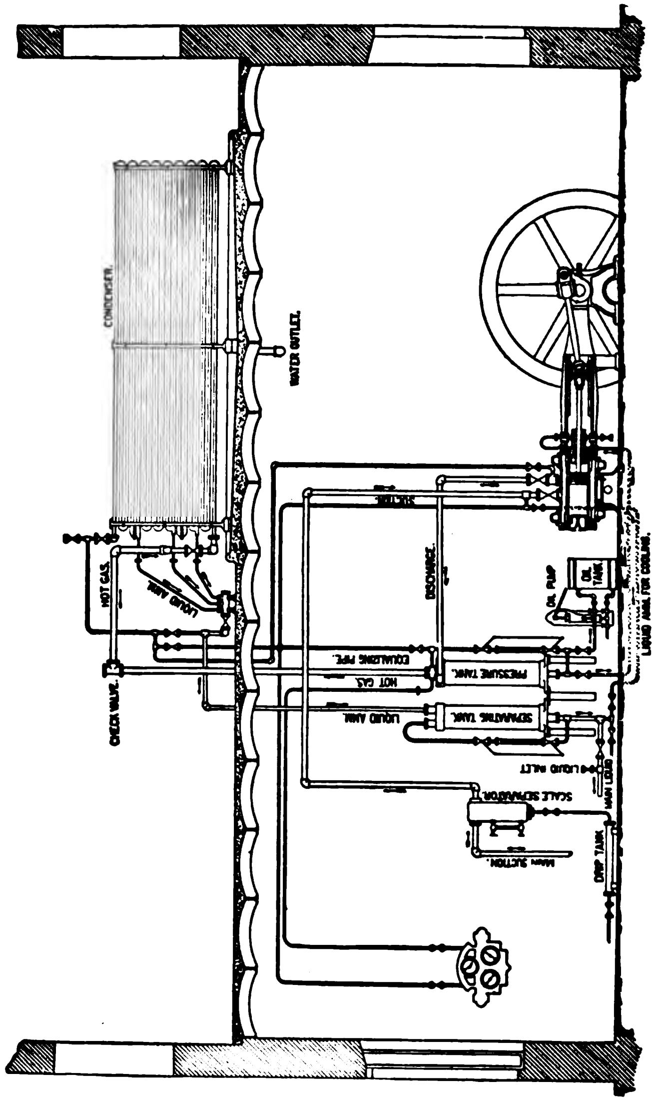
How are compressors divided as regards mechanical arrangement ?

Engines and compressors are either right or left hand. If, when standing at the cylinder end and facing the shaft, the



The figure shows the difference between a right and left hand compressor. It will be noticed that the compressor is the opposite hand of the engine.

fly-wheel is to the left of the frame, the engine or compressor is known as a "left-hand" machine. If, on the contrary, the fly-wheel is to the right of the frame, it is a "right-hand" machine.



The above is a complete elevation of a compression refrigerating plant with horizontal double acting engine driven compressor, showing all the principal piping and apparatus.

How much gas must pass the compressor to produce a given amount of refrigeration?

The table on page 623 shows the number of cubic feet of gas that must be pumped per minute at different suction and condensing pressures to produce one ton of refrigeration in 24 hours. The values given are theoretical ones, and it is assumed that the temperature of the ammonia entering the evaporating coils corresponds to the temperature of condensation at the pressures given, and no allowance is made for unavoidable losses.

To obtain the net refrigerating effect of a compressor, what is, therefore, necessary to determine?

1. The suction (or back) pressure.
2. The temperature at which the ammonia enters the refrigerating coils.
3. The percentage of allowance to cover unavoidable losses.

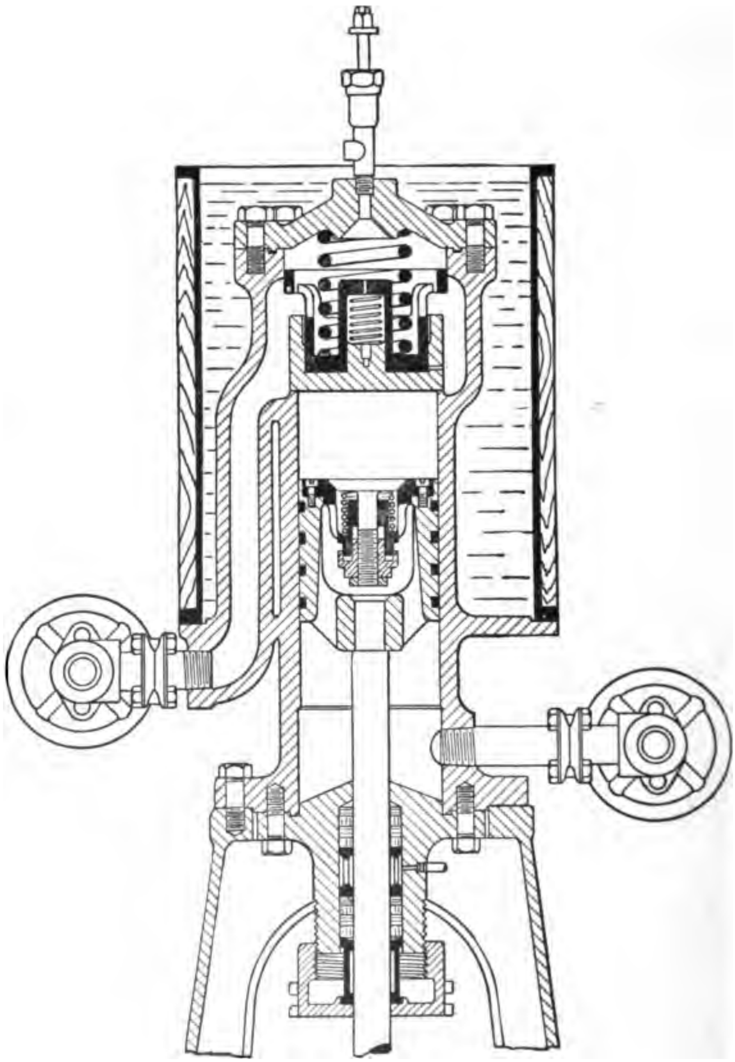
What is a good average?

In the operation of a plant it has been found that the following conditions represent a fairly average practice :

Back or suction pressure 15.67 pounds above atmosphere (at which pressure ammonia evaporates at zero Fahr.), condensing water at 60 degrees Fahr., which gives ammonia liquid a temperature of about 65 degrees Fahr. with a corresponding gauge pressure of 104 pounds above atmosphere ; under these conditions it requires the handling of about 7,500 cubic inches of gas per minute to produce the effect equal to the melting of one ton of ice per 24 hours.

Is the area of the suction valve of great importance?

The freedom with which the ammonia enters the compressor has a very great bearing upon the efficiency and capacity of same. It is surprising to note how little attention this important point has received from designers of compressors.



The above compressor is of the single acting vertical type showing the arrangement of the water jacket. The cylinder is provided with a large flange near the bottom on which the sheet metal jacket is attached. This jacket is covered with a wood lagging to add finish to the appearance of the machine.

What are a few of the leading directions in operating a compression plant ?

A refrigerating plant requires but little more care than an ordinary power plant. The care of the engines, boilers, pumps, and all connections is exactly the same.

The additional work required centers in the handling of the ammonia and the ammonia compressor.

Carry as high suction pressure as possible. The less difference there is between the suction pressure and the condensing pressure, the more economically the plant can be run.

The higher the suction pressure the greater the weight of the ammonia circulated through the plant, and the greater the capacity of the compressor.

Is there a limit to the suction pressure ?

The only limit is the temperature of the brine in a brine plant or of the rooms in a direct expansion plant.

Study carefully the table of boiling points of ammonia, and carry such a suction pressure that the boiling point of the ammonia will be about 10° F. below the temperature you are handling.

Are double-acting compressors practical for vertical arrangement ?

Double-acting pumps on their downward stroke do not expel all the gas, owing to the fact that it is impracticable to use an arrangement of outlet and inlet valves to avoid large waste spaces. These clearance spaces are filled with compressed gas on the downward stroke ; part of the charge that is compressed is not expelled, and expands back as the piston recedes, thus preventing the reception of a full charge on the next stroke.

What is the most serious disadvantage of a double acting compressor ?

With a leaky piston the gas plays back and forth past the same with great loss of power.

What advantage has a double cylinder over a single cylinder compressor ?

In case of accident to a double cylinder pump, the suction and discharge stop valves may be closed on the disabled side only, and the other pump **may continue to run,** and in most cases, if speed is increased, **the work will go on the same as before,** the disconnected pump being examined or repaired at leisure.

Could a single cylinder double-acting compressor be kept in service while being repaired ?

If the valves on one end of the cylinder give out, and each end is supplied with suction and discharge stop valves, the damaged end of the cylinder could be cut out by closing the stop valves on that end, and the valves may be taken out to be repaired while the compressor is operated single-acting.

What is the effect of back pressure on the capacity of a compressor ?

Other conditions remaining the same, a reduction in the back pressure indicates that the cylinder is filled with less weight of gas, consequently the weight of gas pumped per stroke, that is the capacity of the compressor, is reduced.

How are dry compressor cylinders water-jacketed ?

In vertical compressors they are simply small tanks inclosing the walls and high enough to immerse the top head, the water then running off. Horizontal compressors are water-jacketed with the jacket cast integral with the compressor cylinder.

How much jacket water is required for the compressor ?

With a low condensing pressure, say 90 to 105 pounds, 10 to 15 gallons of water per hour per ton of ice making capacity will usually be found ample, but if the condensing pressure runs up to 140 or 150 pounds, 45 to 50 gallons per hour may be needed. The amount should be as large as possible.

Why is careful watch of the expansion valves necessary?

While we do not wish to operate the compressor wet, we do want the refrigerating coils filled with liquid which is at a low pressure and temperature, because when in this condition it is capable of absorbing its greatest amount of heat from places to be cooled, which will depend upon the rapidity with which it is circulated, the degree of which will again depend on the character of work to be performed and whether single or double pipe coolers are used. The operating engineer should pay close attention to the adjustment of the expansion valves, in order to so balance the system that the compressor shall be dry and the circulating coils wet.

TABLE GIVING REFRIGERATING CAPACITY OF "YORK STANDARD" MACHINES UNDER DIFFERENT SUCTION OR BACK PRESSURES.

Diameter Compressors Inches	Diameter Engine Inches	Stroke Inches	Suction or Back Pressure—Gauge					
			5 Pounds	10 Pounds	15.67 Pounds	20 Pounds	25 Pounds	30 Pounds
7½	11½	10	6	8	10	11	13	15
9	13½	12	13	16	20	23	26	29
11	16	15	19	24	30	34	39	44
12½	18	18	26	33	40	46	52	59
14	20	21	39	49	60	69	78	88
16	24	24	58	73	90	103	118	132
18	26	28	81	102	125	143	163	184
20	28½	32	114	142	175	200	229	258
22½	32	36	146	183	225	257	294	331
25	36	42	194	244	300	343	392	442
30	44	48	324	407	500	571	654	736

The capacities given above are figured at a constant speed of machine, and are based on 60° condensing water.

What is the basis of these calculations?

The commercial rating of York machines is based on 15.67 pounds back pressure, at which pressure ammonia evaporates at 0° Fahrenheit.

The icemaking capacity of a machine is about 6/10 of its refrigerating capacity.

How may the capacity of a compression machine be increased temporarily when necessary?

By increasing the quantity of the condensing water, at the same time speeding up the compressor and giving the expansion valve more opening.

Explain why this proceeding should give more refrigeration.

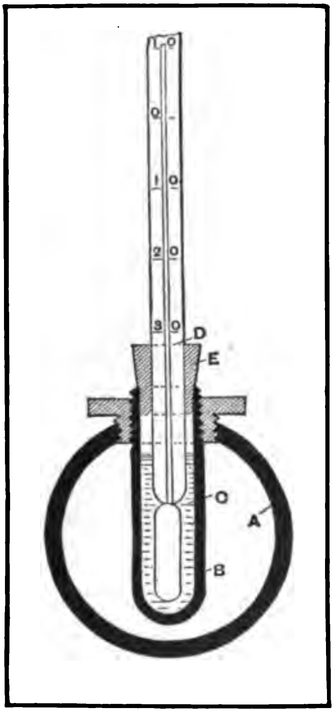
A larger quantity of condensing water will necessarily carry off more heat, and thus take care of more heat brought by the cooling agent from the refrigerating rooms. If we now increase the speed of the compressor we enable the machine to circulate more gas, and thus by increasing the opening of the expansion valve this extra amount of gas will be supplied at the expense of heat from the cooling rooms.

If we should increase the speed of the compressor without increasing the cooling water or opening the expansion valve what would happen?

We would lower the pressure in the expansion coils and increase the pressure in the condensing coils. This would cause a momentary drop in temperature in the freezing rooms due to the suddenly increased evaporation, but as the heat would not be carried off fast enough by the condenser we could not keep this up for any length of time ; the expansion valve would not admit sufficient liquid to make up for the extra evaporation, and the tendency would be to clear the expansion coils of all liquid so that they would contain only gas, which being in a state of vapor would have but little heat absorbing qualities.

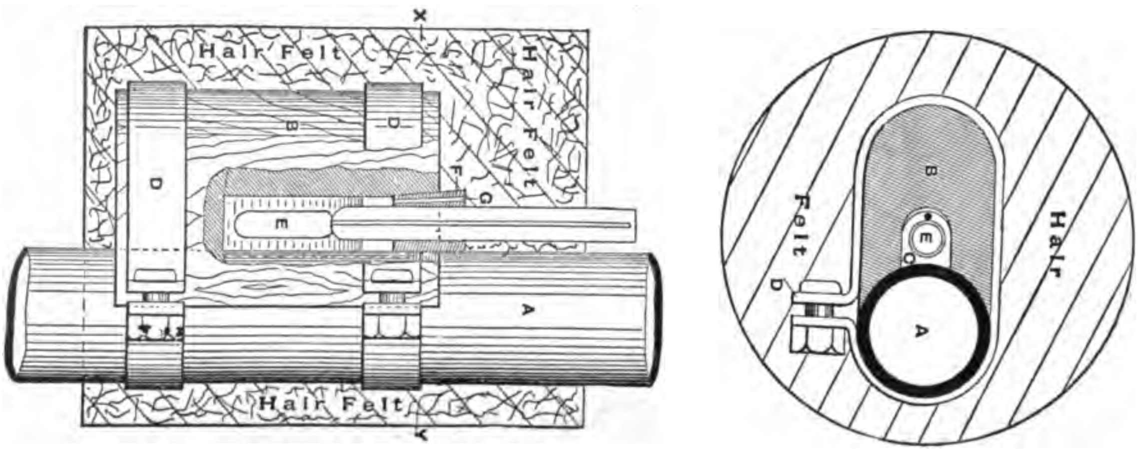
What would be the effect upon the economy of the plant?

It would be attempting to do just the opposite to the ideal conditions. In other words, instead of running with as high a



This view shows a mercury cup attached to a large pipe for the application of a thermometer. For detailed explanation, see page 104.

back pressure and as low a condenser pressure as possible, we would run with a low back pressure and a high condenser pressure



These figures illustrate a very good way of attaching a thermometer to a pipe which is too small to be tapped for a mercury cup. See page 104 for explanation in detail.

Are thermometers of value in keeping track of the work of compressors?

Thermometer cups should be inserted in the common suction and the discharge lines of each cylinder. The mere fact that one discharge pipe is warmer than the other is sufficient evidence that the valve is at fault. In general, however, the crank end runs warmer than the head end, and this must be determined experimentally when it is known that the compressors are in good condition. This difference may be about 6 degrees Fahr. We can assume with reasonable accuracy that the rise in temperature over the normal rise is an index of the loss.

If the gas entered at 50 degrees and is discharged at 200 degrees at one end and 215 degrees at the other end, assuming that when the compressor was operating perfectly the two discharges were equal, the loss in one end is the ratio of 15 to 150, or 10 per cent. Since this occurs in only one end of the engine, the total loss is but half, or 5 per cent. Thus it is seen that a comparatively small loss can very quickly be detected.

How can a loss be traced to the suction or discharge valve?

Having located the cylinder end which is at fault, it is then to be determined whether the trouble lies with a suction or discharge valve. This may be done by taking a double indicator diagram of the two ends of the cylinder on the same card. These diagrams should properly have their compression lines intersect at the center of the card. If the thermometer has shown a serious error, one of these compression lines will lie above the other at the center. If the compression line of the offending end is above that of the other end, it proves that its discharge valves are leaking back, and if the line is below, the fault is with the suction valves.

Compressors with clearance in valve ports may show variation from this rule, as the ratio of clearance to piston displacement is greater at the crank end on account of the piston rod.

Explain how a mercury well may be placed in a large pipe.

Referring to the figure on page 101: The pipe A is tapped to fit the thread of the mercury cup B, which is filled three-quarters full with mercury, and the thermometer D having been introduced and secured in its place by the cork E, the whole is so wrapped in hair felt as to prevent the atmosphere having any effect upon the temperature of the mercury C.

Explain how a mercury well may be attached to a small pipe.

Referring to the figures on page 102: A block of wood B, is shaped so that one side will be a neat fit around the pipe as shown. The cavity C is then cut out the right depth for the thermometer, and the block attached to the pipe A by means of the clamps D D after the surface which is to go next to the pipe has been well covered with red or white lead. The cavity C is then filled three-quarters full with mercury, and the thermometer E is introduced and secured by the cork F. The whole is then well covered with hair felt and wrapped with canvas. The hole G in cork F is simply a vent hole to accommodate the expansion of the mercury. The upper figure is a section through X-Y.

Has ammonia any value as a lubricant?

It has to a slight extent.

How long ought a properly packed piston rod to last?

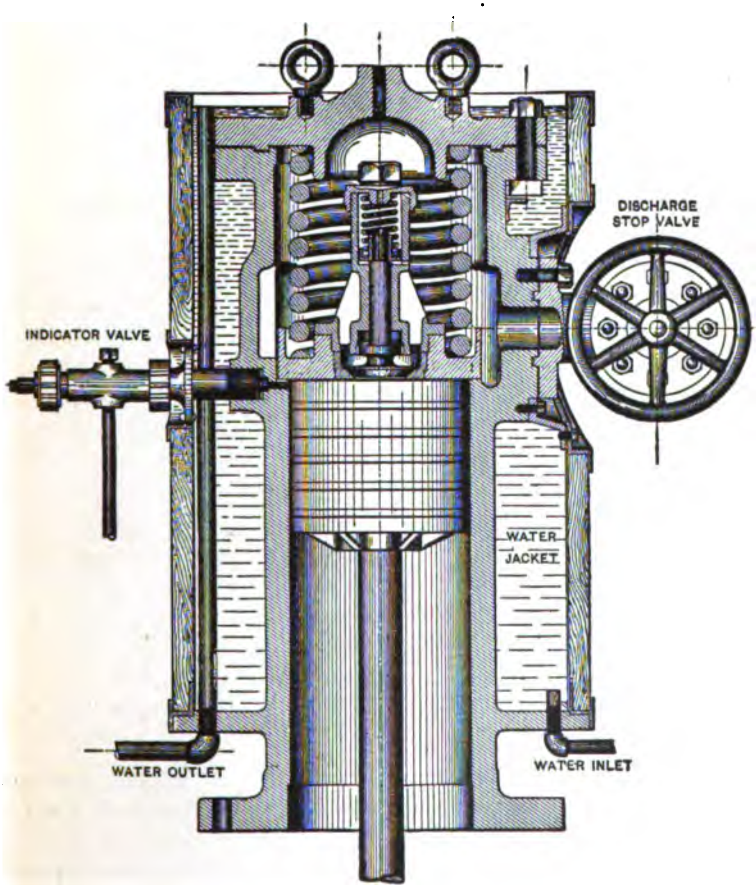
It may not require repacking for six months.

Is it much more difficult to keep a double acting one packed than a single acting one?

In the latter the pressure may not be more than 28 pounds while in the former it may run from 125 to 280 pounds.

What is a general rule as regards insulation of piping in a refrigerating plant?

All the pipe that is not doing work should be insulated



A type of single acting false head Frick compressor, showing the arrangement of the discharge valve and spring holding down the head; the water piping is entirely confined to the bottom of the cylinder.

What special attachments are made on the Eclipse machines for pumping out for repairs ?

They are provided with a by-pass system which enables the engineer to exhaust the ammonia from any part of the machine, and temporarily store it in any other part.

Give directions for pumping out one of the cylinders on compressors of small machines, say up to 20 ton.

Referring to figure on page 107: To exhaust gas from compressor M: All valves closed. Open valves 2, 5 and 8, run machine slowly until compressor cylinder is exhausted, then close valve 8, when pipe A and cylinder head may be removed.

To exhaust gas from compressor N: All valves closed. Remove pipe B, place pipe section A connecting valves 6 and 7, open valves 1, 6 and 7, run machine slowly until compressor cylinder is exhausted, then close valve 7, and cylinder head may be removed.

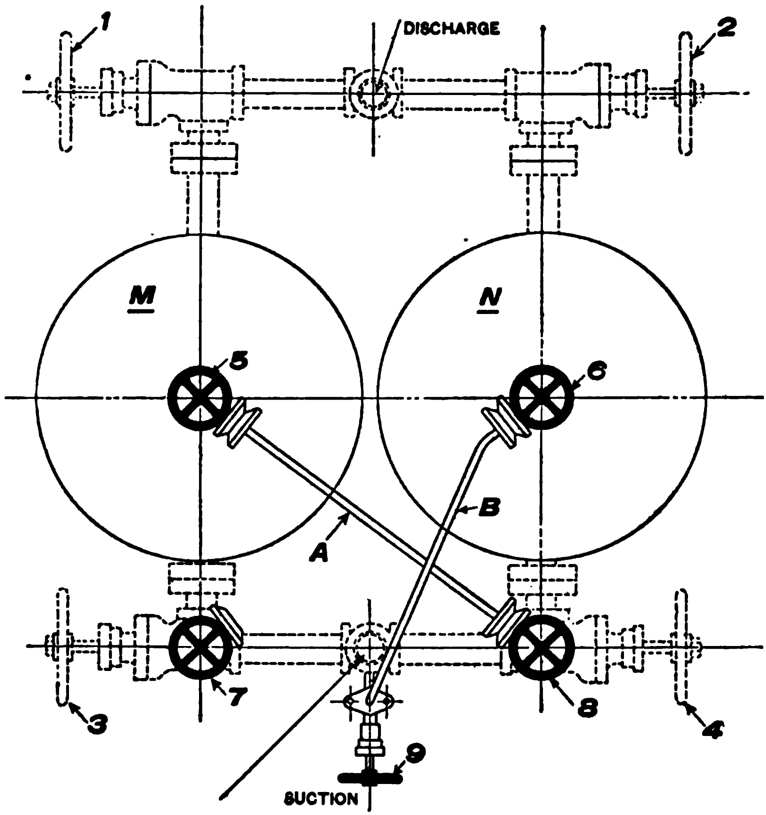
How may the condenser be pumped out ?

To exhaust ammonia condenser and store in evaporating coils or low pressure side: All valves closed. Pipe sections A and B in place as shown. Open valves 1, 5 and 8; 6 and 9. Run machine slowly.

How may the compressors of larger machines, say 25 ton and over, be exhausted ?

Referring to figures on pages 108 and 109: To exhaust gas from compressor B: All valves closed. Open main discharge stop valve A^1 and by-pass valves 2 and 3. Run machine slowly until compressor cylinder is exhausted, then close by-pass valve 3 and cylinder head may be removed. After replacing cylinder head the air may be expelled by closing main stop valve A^1 and discharging through purging valve on head of cylinder A.

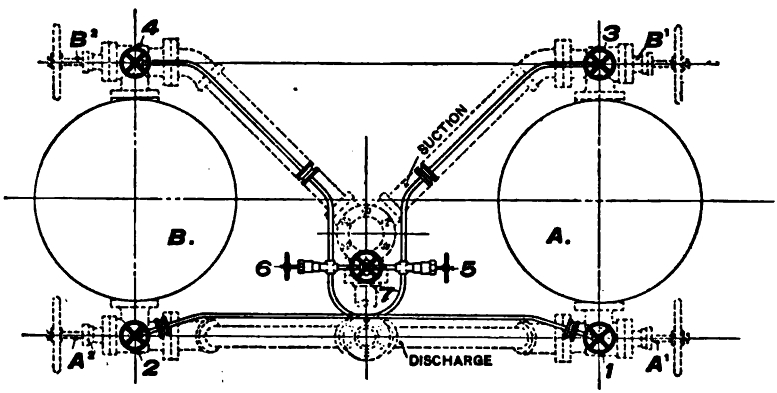
To exhaust gas from compressor A, proceed in same manner, using opposite set of valves.



In the above figure M and N are the compressor cylinders of an Eclipse machine. 1 and 2 are the main discharge stop valves; 3 and 4 the main suction stop valves; 5, 6, 7 and 8 are the by-pass valves and A and B are the by-pass pipes.

How is the condenser exhausted on those machines ?

To exhaust ammonia condenser and store in evaporating coils or low pressure side: Open main discharge stop valve A^1, by-pass valves 1 and 4, thus connecting to suction of cylinder B, and expelling gas by opening by-pass valves 2, 5 and 7 into main suction pipe. Run machine slowly.



This is a plan view of the by-pass piping of the Frick compressors above 25 ton capacity; the circles A and B being the cylinders.

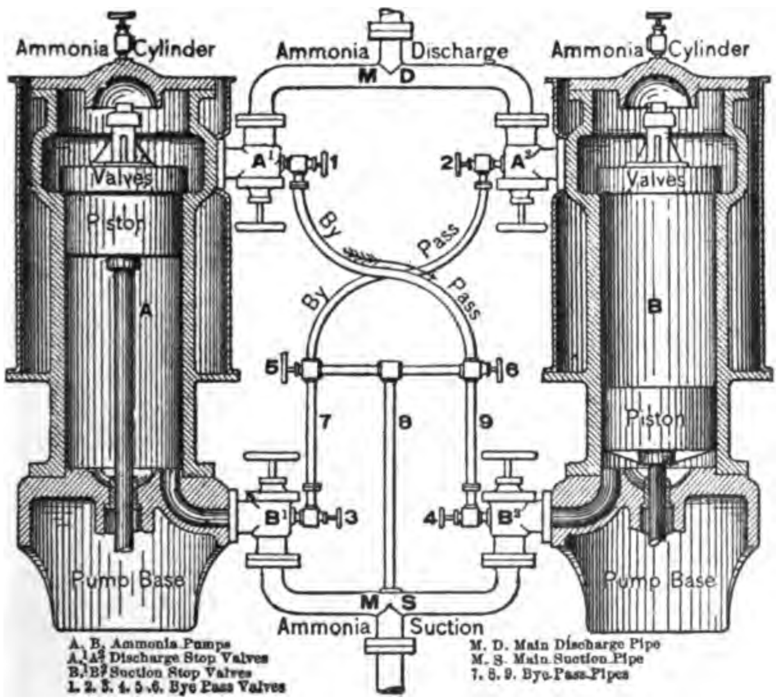
By using opposite set of valves the other cylinder may be used, as one is used to exhaust the gas from the discharge through by-pass, while the other expels it through the other portion of by-pass into the suction pipe and low pressure side.

How should the by-pass valves be kept when the machine is running on regular duty ?

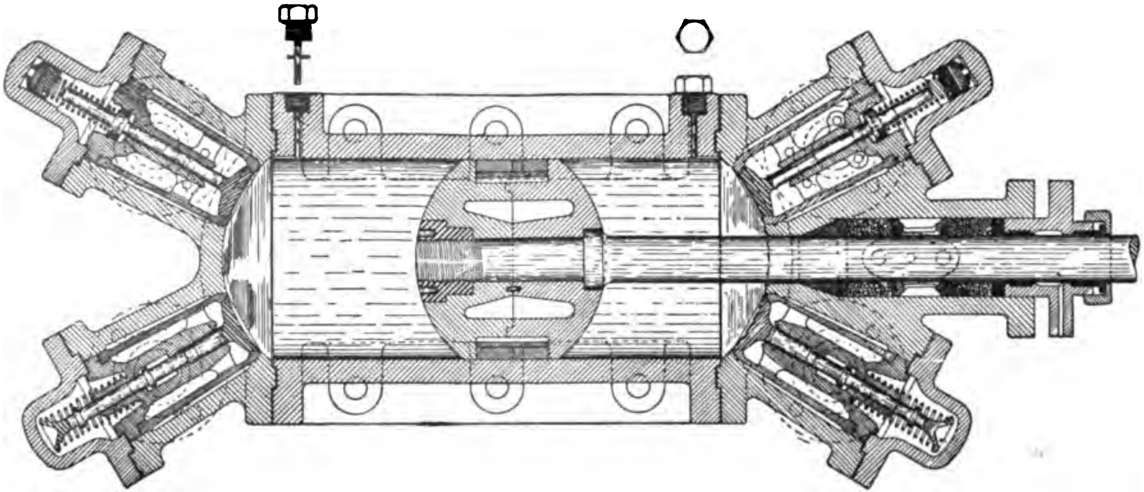
They must be kept closed.

Why should one be careful about bringing a naked light near a broken joint or confined space where a leak may be suspected ?

An explosive vapor may form.



This illustration showing a vertical section of a pair of single acting Frick compressors, gives a clear view of the bye-pass piping.



The above is a section through the cylinder of a Linde compressor; the piston is made nearly spherical, and the heads are shaped so that but very little clearance is obtained. The arrangement of the valves is clearly shown. It will be noticed that there is no water jacket, as the compressor operates on the wet compression plan.

Why do ammonia connections need more careful packing than those for steam ?

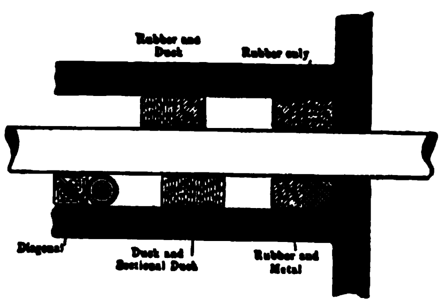
Ammonia is more difficult to pack than steam, not because it is harder to hold back ammonia, but because a loss of ammonia means a greater loss of money, and the ammonia is quite offensive. As a result, it is demanded that ammonia be packed tighter and more surely than steam. The problem is still further complicated by the fact that there are so many different kinds of machines. The use of ammonia for cooling purposes is not as old as the use of steam for power, but there are many machines now is use which are old and improperly made.

How is the matter of packing further complicated ?

The conditions may change very rapidly. One minute the temperature of the stuffing box may be 10 degrees below freezing and shortly afterward it may rise to 300 or 400 degrees above. When the packing is warm, the rubber will expand and pack satisfactorily, but when the rubber is cold, it contracts, and unless the gland be adjusted quickly, ammonia will leak, and, if adjusted for low temperature and a sudden high temperature appears, the rubber will expand and press against the rod with unnecessary force, producing friction which raises the temperature high enough to burn out the packing. A good engineer must adjust the gland and the expansion valve at the same time, that is, adjust the gland to take care of immediate conditions and the expansion valve so as to change these conditions. If less cooling is called for in the cooling coils, there is a possibility of a "freeze-back" and the cylinder of the compressor becomes very cold. The expansion valve must then be adjusted and at the same time the gland must be adjusted to compress the packing. As soon as conditions become normal, the cylinder will become warm and the gland must be slacked off to release the pressure on the rod.

Describe the construction of the stuffing box.

On an ice machine the construction of the stuffing box is peculiar. As a rule it consists of three sections, the end sections being separated by a separator, spool or lantern, which occupies the middle section of the box. Through this middle section a current of oil is kept passing as a means of lubrication. It is difficult to recommend any special form of packing as it depends upon the individual taste of the engineer. Some engineers will pack with pure rubber ring entirely. Others will use rubber and



In this illustration are shown the various approved packings used for ammonia. Any of them may be employed independently or two or more of them may be used together.

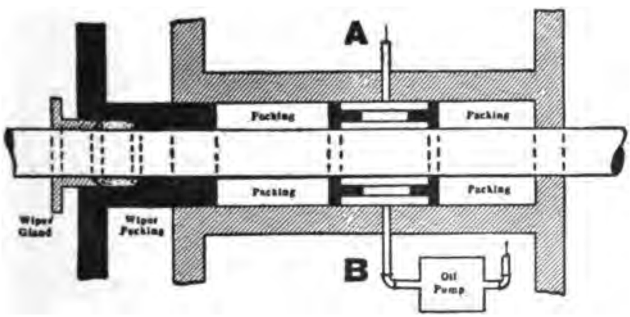
ordinary duck expansion packing alternately. Still others use an expansion ring and a sectional ring so as to secure a quick adjustment. A great many use a diagonal packing with excellent results. A skillful engineer will use any of these packings with success. The great objection to many of them is that the loose fibers, which become detached by the action of the rod or of the oil, manage to get into the oil wells or small pipes through which the oil passes, and clogging them up, may prevent the flow of oil and consequent lubrication.

Where does the stuffing box need special care ?

In a double-acting compressor the stuffing box is subjected to the high pressure gas, and, therefore, requires more careful attention. However, the manufacturers of modern double acting compressors have improved the stuffing boxes to such an extent that the danger of leakage is but trifling.

Is the single-acting compressor less subject to stuffing box trouble ?

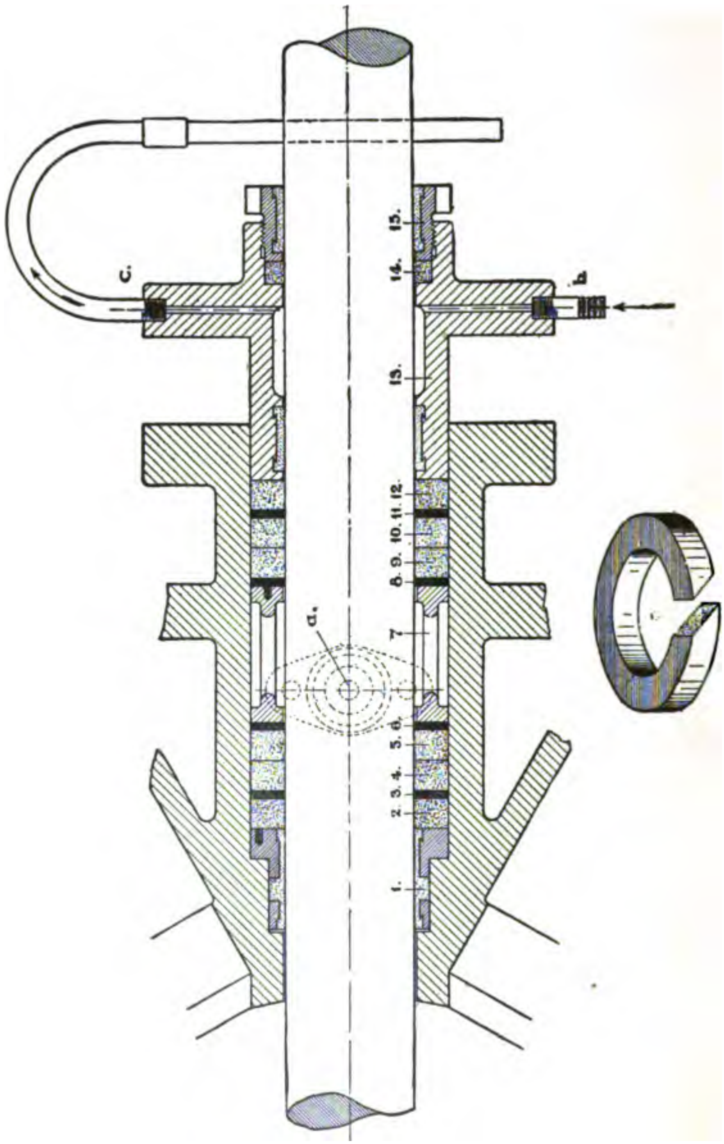
In the single-acting pump, because of the low pressure on the stuffing box, the leakage of ammonia past the piston rod is easily prevented. There is, however, some pressure upon the packing and it should, therefore, not be neglected, as the leakage under as low a pressure as 15 pounds is quite serious.



This figure shows a section of a stuffing box for a compressor cylinder. At A and B are shown openings to which the oil pipes connect. These openings lead to a cavity surrounding the piston rod, and which is filled with oil. The oil is circulated through this annular cavity by means of a pump, which returns it to a reservoir after circulation. The oil is thus circulated in a continuous cycle.

How should a compressor stuffing box be constructed ?

It is well to have a compressor stuffing box in two parts or double packed, the inner to be of proper proportion to hold the packing against the loss of ammonia and the outer of only slight depth to retain the lubricating oil within the annular space provided between the two, and through which the rod passes in its travel.



The above is a cut of the Linde stuffing box; 2, 4, 5, 9, 10, 12 and 14 are packing rings made expressly for the purpose out of a special composition of rubber; 3, 6, 8 and 11 are metal rings made of pure tin; 7 is the lantern forming an oil storage in the middle of the stuffing box; 13 is the stuffing box gland, which is supplied with oil through *b* and *c*; 15 is the oil gland; 1 is a guide bushing; *a* is the oil inlet.

Describe the process for packing the Linde type stuffing box.

These metal rings should keep the rubber rings in proper shape and condition; the inside diameter of the metal rings should always be one-sixteenth of an inch larger than the piston rod.

If the metal rings fit in the rod too tightly, the whole packing will very soon be spoiled, and cause cutting of the rod. If new metal rings have to be used, **never** cut them in two; but disconnect the piston rod from the crosshead in order to get the solid rings on. **Never pack the compressor without the metal rings.**

How should the rubber rings be cut ?

The rings must be cut diagonally as shown on page 114, and it must be constantly borne in mind that the rings must never be used in one solid piece.

The rubber rings should fit new rods tightly; and may be used just as well on rods that have been turned off once as on new ones.

Should the glands and guide bushing be allowed to become worn ?

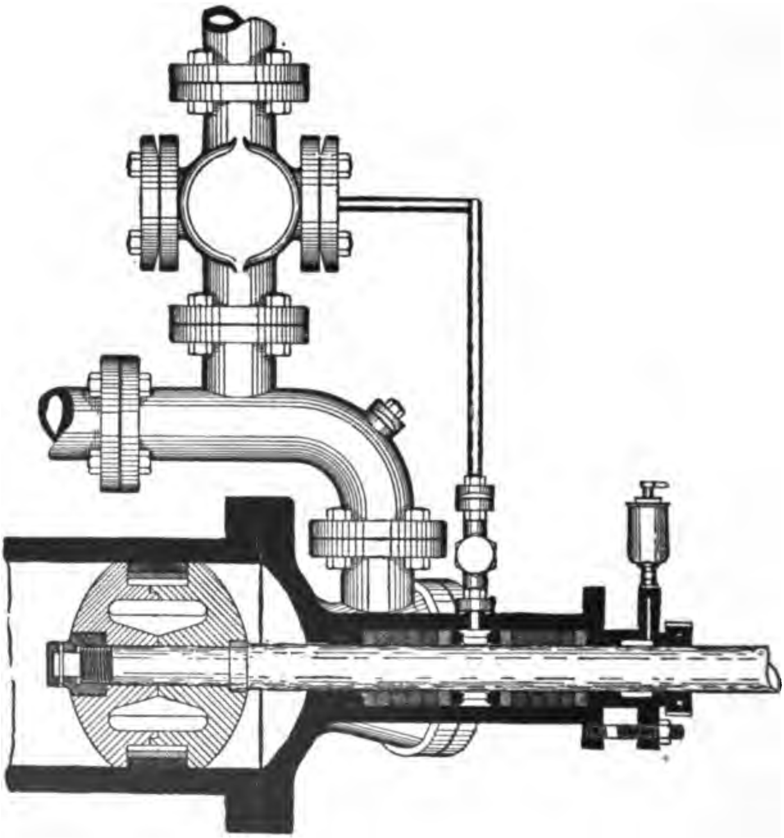
The glands and guide bushing must fit the piston rod properly. If the piston rod needs to be turned off, these parts should be re-babbited.

Where is the oil for the lantern taken from ?

The oil supply is taken from the oil trap; the connection between the stuffing box should always be left open.

How tight should the oil gland be ?

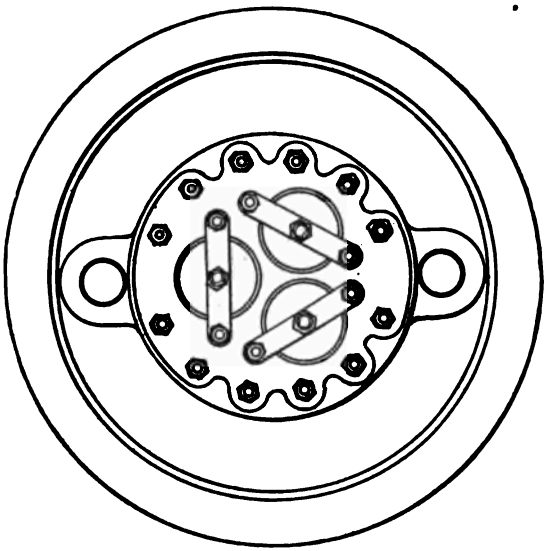
The oil gland should be just tight enough to keep the oil in the stuffing box gland. When repacking the stuffing box, be careful to place the different parts of the packing according to the drawing. Do not tighten the gland 13 more than is necessary to prevent the ammonia from leaking.



Section through a Linde compressor showing construction of stuffing box and its connection to suction side of compressor.

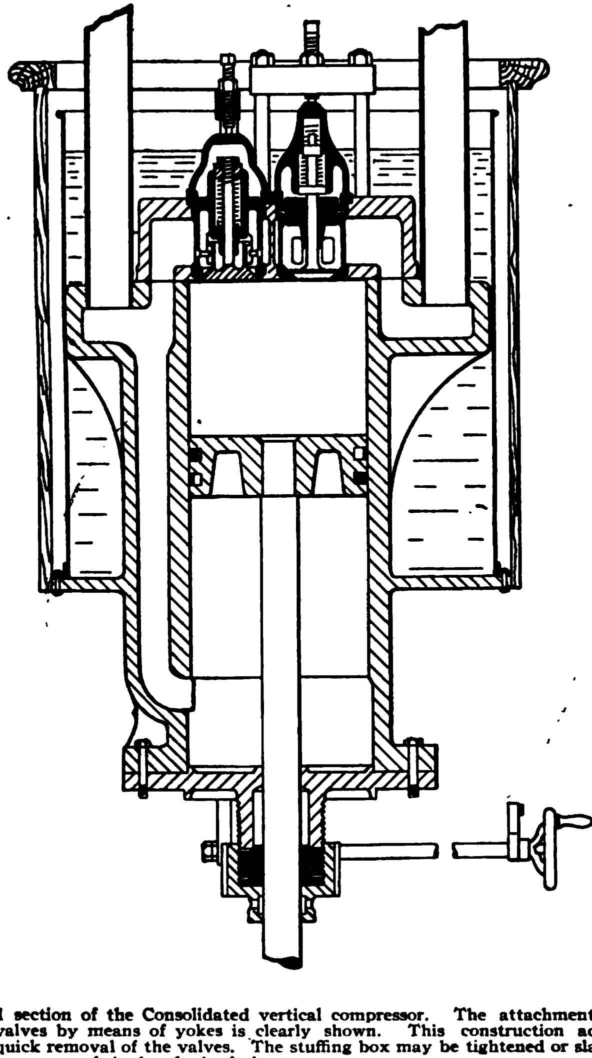
What is the ratio of size between the steam and compression cylinders?

It is common practice to make the steam cylinder of a refrigerating machine two to two and one-quarter times as large as the ammonia cylinder. If the stroke of both cylinders is the same, the area of the steam piston should be two to two and one-quarter times as large as the ammonia piston.



Plan view of Consolidated compressor showing the arrangement of the single suction valve and the two discharge valves.

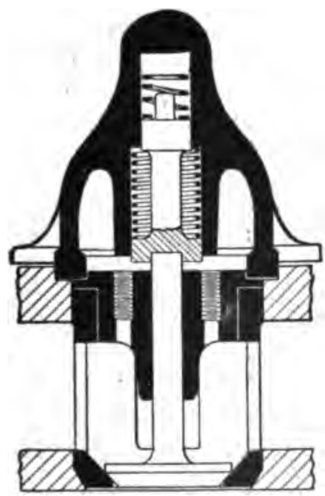
If the strokes are different, the product of the area of the steam piston multiplied by its stroke should be two to two and one-quarter times the product of the area of the ammonia piston multiplied by its stroke.



Vertical section of the Consolidated vertical compressor. The attachment of the valves by means of yokes is clearly shown. This construction admits of quick removal of the valves. The stuffing box may be tightened or slacked off by means of the hand wheel shown.
The shaft of this hand wheel is provided with a worm, which meshes into the worm wheel teeth cut into the periphery of the gland.

How should the compressor valves be looked after ?

A loss of ammonia occurs if the stop valve leaks in case the cylinder must be opened. We must, therefore, attend first to the main stop valves and make them tight by grinding the valve to its seat or replacing the valve ring.

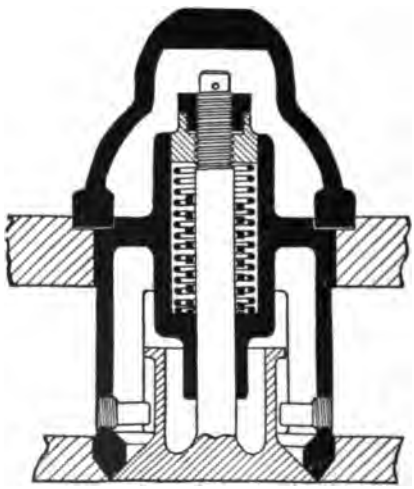


This device is a vertical section through the Featherstone discharge valve. These valves are similar in construction to the suction valve, being so adjusted that they are nearly noiseless in their action. The interior of the valve cap forms a dash pot which contains the cushioning piston and the springs. The flat helical spring in the upper chamber acts as a cushion to prevent the valve stem from striking the end of the chamber.

Then we must do everything possible to make the piston tight. Next come the suction and discharge valves of the compressor.

What is liable to make trouble in the valves ?

Scale and grit of the pipework may pass through the valves, and some parts are caught while the valves are closing. The constant hammering of these small particles of metal or sand between valve and seat make both very rough, so that they cannot close tight.



This illustration is a cross section of the Featherstone safety suction valve ; the valve stem is securely fastened to the plunger by a differential lock nut and split key ; the valve is also provided with a safety head, which holds the valve in the cage should the stem become crystallized and break. The springs are so arranged that the valves are nearly noiseless.

If too rough for grinding, have the valves faced off a little and then grind them to the seat until the surfaces are smooth and without deep spots or holes. See that the valve stems have no shoulders and work free without being too loose in the housing.

How should the valve springs be adjusted ?

Adjust the valve springs, because they will greatly reduce the capacity of the compressor if too stiff, or will not hold the valve in plače if too weak. The suction valve springs if too stiff do not allow the valve to open quickly and wide enough to fill the cylinder with gas of nearly the same pressure as exists in the main line. The suction spring should just hold the valve to its seat if the pressure is equal on both sides of the valve. If the discharge valve spring is too stiff, it takes too much power to open the valve which also hammers too heavy on the seat. If the spring just holds the valve to its seat under equal pressure on both sides, there will be no trouble at all, as the difference in pressure on both sides while the piston is returning, will seat the valves properly.

Do compressor leaks need careful attention ?

Small leaks or imperfections on the steam side are not so important as they would be on the ammonia side, because these two vapòrs are entirely different in their nature as well as action. Steam condenses within the cylinder, and the water resulting therefrom helps to some extent to close up small passages. Even larger leaks increase only the amount of steam used for doing a certain work. The ammonia vapor, while going through the cylinder, does not condense but is heated and becomes a gas, and the loss caused by that portion which passes through even the smallest opening, on account of the great difference of pressure, is very great.

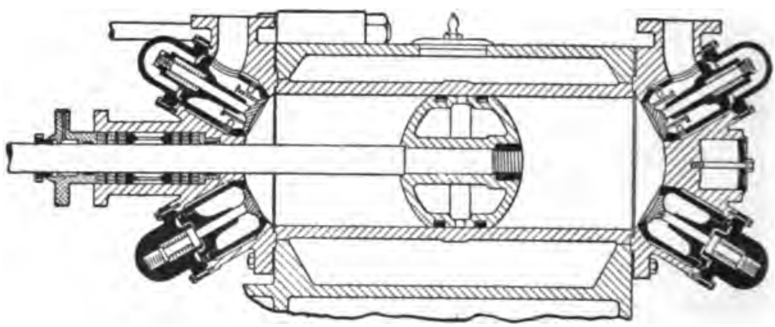
How are sounds in a compression machine located ?

If they seem to come from various places they may be located, frequently, by placing one end of a piece of rubber tubing near the suspected spot and the other end to one ear, closing the other one.

How can faulty action of the valves be detected ?

This can usually be determined by placing the hand upon the inlet and outlet pipes.

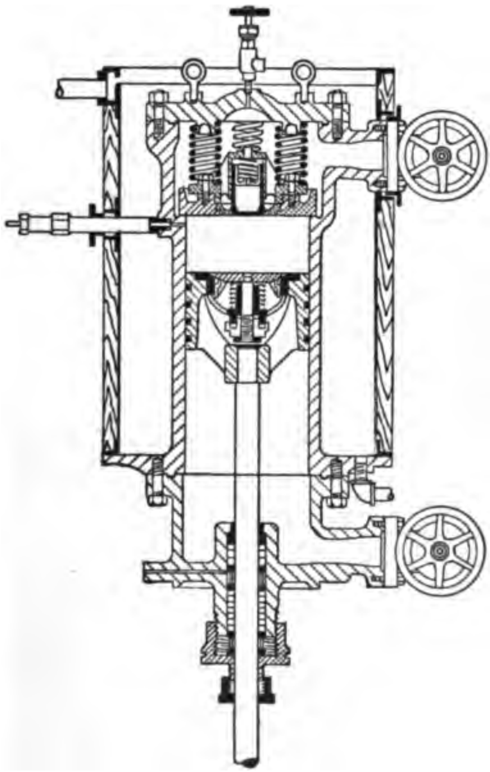
Should the inlet pipe to one compressor, if two single-acting machines are used, or to one end of a double-acting compressor, become warmer than the other, it indicates that the one having the warmer pipe is not working properly and the full amount of gas is not compressed at each stroke. This may be due either to more clearance or leaky valves. The relative temperatures of the pipes may also be determined by the appearance of the frost upon the outside.



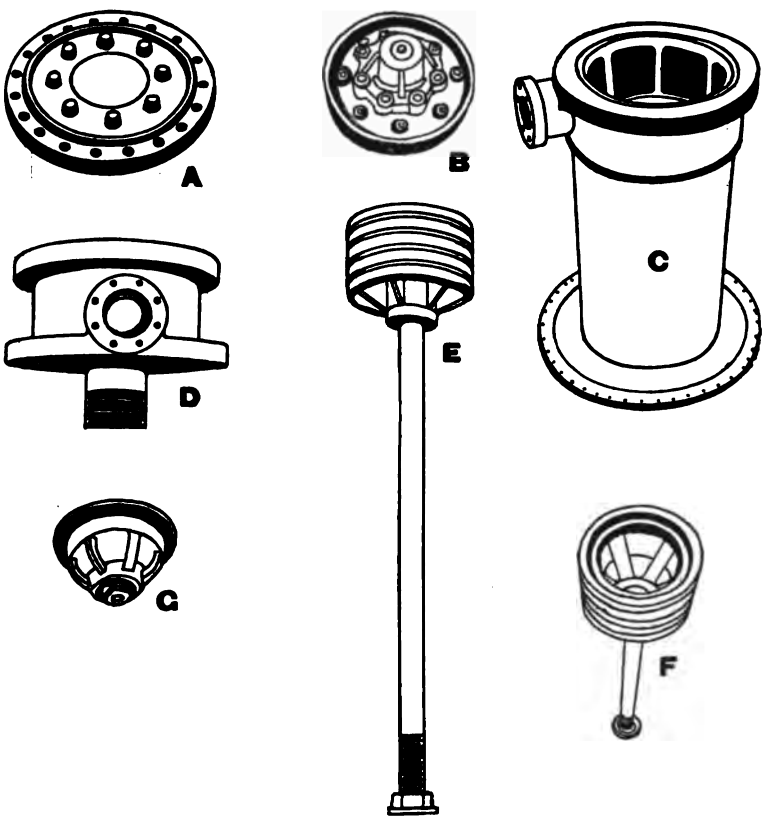
The above section represents in part a double acting horizontal Featherstone compressor; the valves shown are their regular type and are further illustrated in detail on pages 119 and 120.

What is one of the most important gauges ?

For the economical operation of the compressor plant there is but one instrument capable of supplying the normal stimulus necessary to make the engineer pay due attention to the handling of his back pressures and that is the ammonia back pressure recording gauge, having a spring of such strength that a variation of not only 5 pounds, but half a pound can be readily observed.



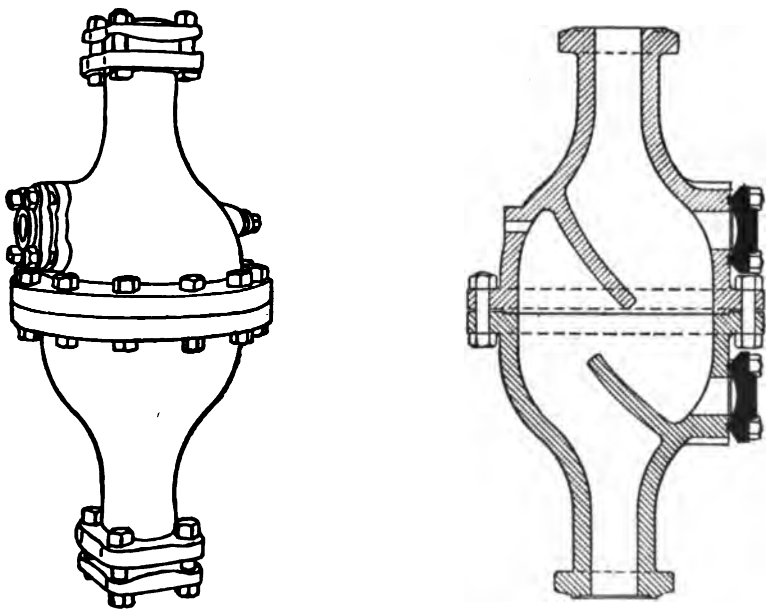
A vertical section of an early type York compressor, showing the false head with discharge valve and springs. Also the suction valve and cage in the piston. The suction valve spring is located so as to tend to lift the valve off its seat, the tension of the spring being sufficient to nearly balance the weight of the valve : thus, very little pressure below the piston, during the suction stroke, will raise the valve. This design is preferred in all false head single acting compressors, as it enables the compressor to draw in a full charge. During the discharge stroke the valve is seated partly by gravity and partly by the pressure above the piston. As the speed of the machines is low, there is ample time for the valve to set itself when passing the bottom center..



These are the most essential parts of the early type of the York compressor. A is the stationary head. B is the false head with valve cage in place. C is the cylinder. D is the cylinder base forming the bottom head and stuffing box. E is a perspective bottom view of the piston and rod. F is a perspective top view of the piston and rod. G is the suction valve cage.

What is an old method of locating a noise in an engine or pump cylinder ?

By placing one end of a wrench or piece of metal on the cylinder head and the other between one's teeth, closing both ears. Every sound in the cylinder can easily be heard.



The above strainer or scale separator may be placed in a horizontal or vertical position in the suction pipe of the compressor. The scale is intercepted by the baffle plates.

How may the strainer be kept in order ?

A screen of very fine mesh, but of sufficient area to permit of the full suction flow, is so arranged as to be accessible through the flanged opening at the side, and the accumulated matter may be removed from time to time.

In dry compression, how is the heat of compression disposed of ?

In dry compression, the heat of compression is carried off by water jackets to a great extent.

Is the jacket of a compressor sufficient to carry off the heat of compression ?

The jacket of the average ammonia compressor is inadequate for the performance of its duty in the cooling of this unit. The cooling effect of the jacket is largely a skin phenomenon limited at high speeds to a thin layer on the interior of the cylinder walls. The type of compressor, utilizing an auxiliary oil circulation through the compressor, was designed for the purpose of producing an internal water jacket in its effect and for the elimination of clearance evils as well. That the net result was an increase in complexity in the operation of the compressor, with a loss rather than increase in efficiency, is now an accepted conclusion.

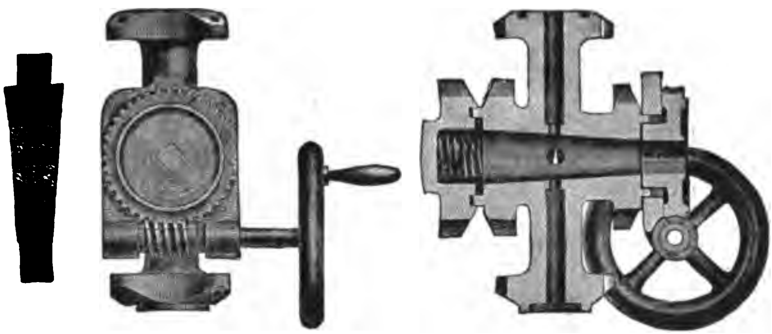
What can be said in favor of dry compression ?

In dry compression the ammonia vapor is essentially a gas and is similar in its behavior during compression to air in its effects in the ordinary air compressor. Cylinder heating is very great, the mean effective pressure throughout the stroke is much higher than is necessary, and the clearance effect is at its maximum. A certain amount of ammonia, however, passes through the compressor at each stroke, and this amount is definitely known and can be relied upon. In dry compression every ounce of ammonia gas which passes through the cylinder is ultimately used for the production of available refrigeration.

What are the objections to the dry compression system ?

When ammonia gas is being compressed in the compressor, say from a pressure of 20 lbs. to 175 lbs. a considerable amount of heat is developed. This heat is transmitted to the compressor cylinder and all its parts, and if no means was provided for cooling

such parts, the compressor cylinder and especially the valves and piston would soon be in such a heated condition that they would be unfit for work. To extract this heat, most refrigerating machinery has a water jacket around the cylinder to keep it cool. As this, however, does not reach the piston and the valves, oil is injected during the working of the compressor.



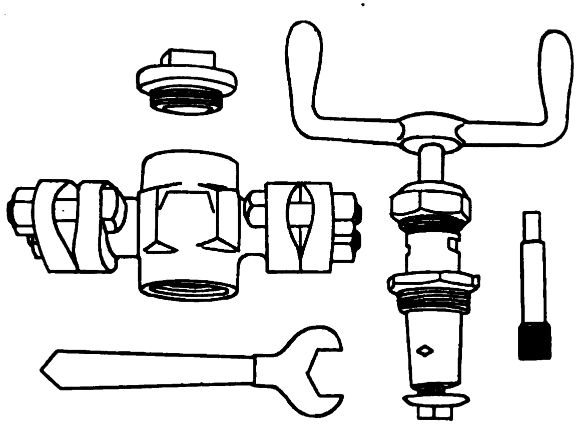
A De La Vergne expansion valve showing its capacity for delicate adjustment.

Why is the use of oil objectionable ?

The superheated ammonia vapors transform part of the oil into gas, which passes through the oil traps into the condenser where it will condense and be carried with the liquid ammonia into the refrigerator coils. Here, the oil will settle on the inner surface of the pipes, where it forms a thick soapy coat. This coat of oil acts as an insulator and prevents the cold ammonia from coming in contact with the pipes, thereby preventing them from doing their full work. In some cases this accumulation of oil in the refrigerator system chokes the pipes, and consequently the machinery has to be stopped for days to enable the engineer to blow out the pipes with steam or air to get rid of the oil. This not only means loss of time, but also great expense.

What other method is there of avoiding cylinder heating by what is called wet compression?

Two other methods exist for eliminating the difficulties of ammonia compression. One is based essentially upon design of compressor and valves, with very slow speed action and the development of a compressor in which these effects are reduced to their minimum by conscientious attention to design and operation. The other development is based upon the fact that

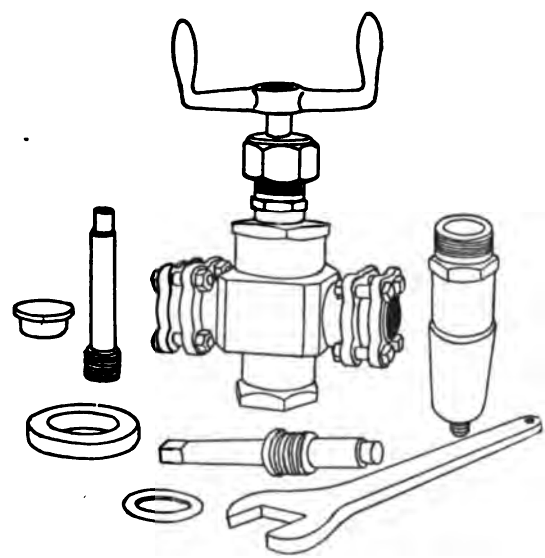


The Triumph expansion valve. The opening in the plug is made diamond-shaped, which allows a very fine adjustment.

ammonia passes, in its cycle, through its condensation temperature, and through a portion of its operation is in the form of a saturated vapor with possibilities of condensation and compression at this time analogous to steam in its operation. Thus we have what is known as dry compression and wet compression, respectively.

In wet compression what becomes of the heat of compression ?

In wet compression the heat of compression is absorbed by re-evaporation of liquid ammonia, and thus the mean effective pressure is raised by an amount due to the gas produced, and the duty of the ammonia condenser is considerably increased.



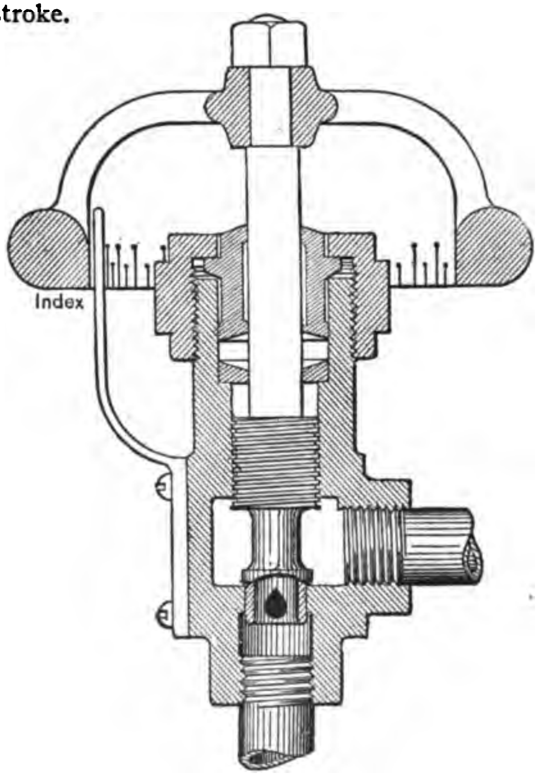
Triumph expansion valve with square flanges, showing details.

The residue diminishes the capacity of the compressor due to the after heating effects of the cylinder walls.

As a general thing the compressor can operate at a considerably higher speed with less loss in efficiency than can be done in the dry compression system.

What can be said in favor of wet compression ?

In the wet compression system, the ammonia gas is compressed in contact with its own liquid ; that is, a small amount of ammonia liquid is injected into the compressor at the beginning of each stroke.



The Eclipse expansion valve with index wheel. The disk has a sleeve which fits the seat snugly and into this sleeve a pear shaped hole is cut, which allows very gradual opening.

Thus the ammonia vapor is kept saturated throughout the stroke, and the pressure and temperature of the mixture cannot rise beyond that of the liquid until all of the latter is evaporated.

What claims are made for the Linde system of "wet" compression ?

In this system the ammonia compressor is worked cool without the use of any outside agent. This is accomplished by having the refrigerating system so arranged that the liquid ammonia which passes through the pipes does not all form into gas, but that small particles of liquid ammonia are carried back to the compressor, that is, they work with saturated gas. These small particles of liquid ammonia, during the compression period, form into gas and by doing so, absorb part of the heat developed during the compression and so keep the compressor cool.

As ammonia in a state of moist vapor has considerable lubricating qualities, but little lubricating oil is required for the piston.

How high does the temperature go during compression ?

This system is so constructed and regulated that the heat developed during compression, does not go above 125° Fahr. Therefore, with these compressors and machinery no water is required to cool the cylinder, neither is any oil required to be injected into the cylinder to cool the piston and valves. In working the compressor naturally cool, it is obvious that no oil-gases can be formed and carried into the system to coat and choke the pipes, and therefore, the inner surfaces of the refrigerator pipes are kept clean and can always transmit the same amount of cold, and give the same efficiency, even after years of working.

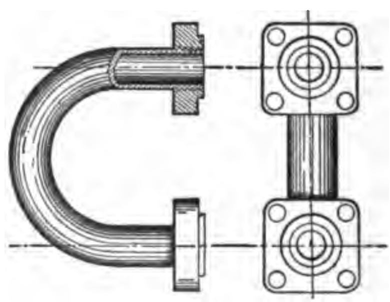
There is a further defect in the compressors which work with overheated ammonia gas, namely, that on account of the high temperature existing in these compressors, the pressure is much higher. Any increase in pressure means also an increase in driving power, therefore it stands to reason that compressors worked with overheated vapors use much more power for driving.

Is there any fixed limit to which wet compression can be carried economically?

The amount of liquid injected depends entirely on local conditions, such as the temperature of the circulating water for the condenser, which is the governing factor of the extent of the compression.

How may this limit be determined?

By careful observation only. If the temperature of the cooling water for the condenser is low, and an abundant supply of it is available, the compression may be carried comparatively low, as the gas will liquefy at lower pressure when its temperature is kept down. The heat of compression, therefore, is much less than in a compressor where high compression is demanded. The

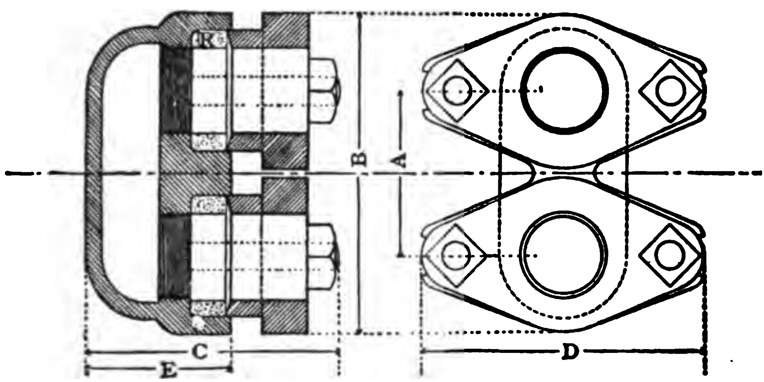


Solid return bend, single pipe, with flange connection.

amount of liquid to be injected into the cylinder can, therefore, be much less, in fact the liquid should be no more than absolutely necessary to keep the cylinder walls at a reasonable temperature. The object of compression, as previously stated, is to get rid of the heat absorbed by the refrigerant in the cooling system, and in order to compel the cooling water in the condenser to take up this heat we must allow the gas to enter the condenser at a higher temperature than the cooling water. If, therefore, too

much liquid be injected very little heat would be carried off in the circulating water, and the capacity of the plant would be greatly decreased, as we would be circulating too much of the liquid between the compressor and condenser without allowing it to reach the refrigerating coils. If this should be carried to extremes, very little refrigeration would be produced although the resistance of the compressor would be as great as if the plant was doing its full duty.

It must be borne in mind that the liquid has been obtained at the expense of cooling water, and any attempt, therefore, to relieve the condenser by over abundant use of liquid in the cylinder would be a fallacy.



In connecting a nest of condenser pipes care should be taken to allow sufficient space for the principal dimensions. A is the distance between pipe centers; B is the overall height; C the overall length; D the overall width; E is the depth of the main body. The soft packing R should be compressed just enough to stop all leaks.

Is there no tendency for the gas to heat in a wet compressor ?

The cooling operation of the wet compressor does not mean that heat is not produced. The same, or at least a definite, amount of heat equivalent to the work done is produced on each stroke of the piston. This heat, however, does not result in an abnormal increase in operating pressure as it does in the case of gas compression, due to two reasons. One is that the resulting

increase in pressure due to heating effect would not be as great in the case of a vapor as in a gas, and the other is due to the fact that the heat as fast as produced is absorbed by the vaporization of a portion of the ammonia liquid present in the cylinder. Thus the utilization of this device results in the elimination of two evils, with the production of two additional ones.

What is the other evil which is eliminated besides abnormal heating ?

The re-heating effect, with consequent diminution in density of the incoming charge and of capacity in the cylinder for the same, is totally eliminated by keeping the cylinder walls cold.

What are the disadvantages referred to ?

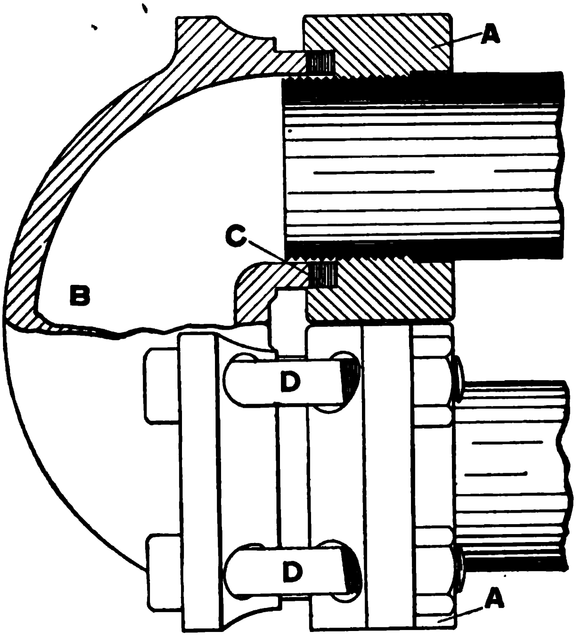
First, the capacity of the cylinder is reduced in turn by the volume of the ammonia liquid injected per stroke, and the work is increased by the fact that the piston operates against the vapor which is produced by vaporization from the ammonia liquid present in the cylinder when the latter is heated by the heat produced by compression.

Second, a portion of the ammonia liquid available for the production of refrigeration becomes no longer available for this purpose, since it is evaporated in the cylinder and its vaporization used to produce cooling in the compressional charge during compression rather than in commercial cooling where desired. Thus, the ammonia which passes through the compressor or through the condenser is no criterion or measure in the wet compression system of the amount of refrigeration produced.

How can we determine whether the amount of liquid injected into a wet compressor is excessive ?

If the liquid is not all evaporated before the compression stroke is practically completed or rather before the discharge

valve opens, it will manifest itself by the comparative coolness of the discharge pipe, as much of the liquid would be evaporated in the discharge pipe, where it is not needed.



The flanges A A are screwed on the pipe with the ends projecting through; the return bend B is then drawn up against the soft packing C by the bolts D. The packing being compressed fills the space between flange A, the pipe and the bend B, making a tight joint.

How can we best observe this temperature?

The discharge pipe should be provided with a thermometer close to the compressor ; it should also have a pressure gauge attached. The table on page 633 gives the temperature and the corresponding pressures of saturated ammonia gas, and by comparing the readings of the gauge and thermometer with the values given in the table, we can see at a glance whether the temperature is excessively low.

Must the readings of the gauge and thermometer absolutely compare with the values given in the table ?

No; the temperature of the gas during compression is considerably higher than that of the saturated vapor, the gas being in a state of superheat due to the work done upon it during compression. It is this heat that we wish to keep down in the compressor, not the latent heat of evaporation. The temperature of the saturated vapor is not high enough to interfere with the proper working of the compressor, in fact, the gas may be discharged at a much higher temperature, the comparison with the table values is merely an approximate guide, and no attempt should be made to approach it too closely.

How would too much liquid affect the compressor ?

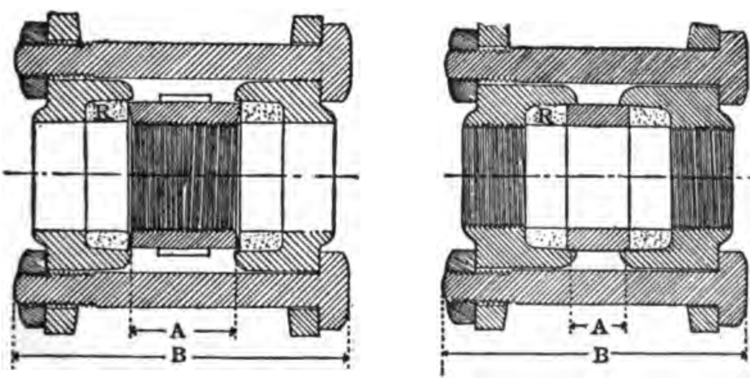
Clearance space in a compressor, if only filled with gas, is not detrimental to the economy of the machine because the work expended in compressing the gas is not wasted, but will be of value during the return stroke of the piston, and the only loss is one of capacity, depending on the pressure and excess clearance space. Where liquid is trapped in these spaces between hot walls and in an agitated state, rapid evaporation occurs during the return stroke thereby reducing the capacity of the compressor on account of partly filling it with this gas, and the work performed for compression of this gas may be considered as lost, as the latent heat for its evaporation did not come from the refrigerating rooms.

Is the loss the same in all compressors ?

Where the discharge valves of a horizontal compressor are on the side of the cylinder the loss is much greater than in a machine with discharge valves at the bottom, as in the latter construction most of the excess liquid flows out at the end of the compression stroke. If we should attempt to run a vertical compressor wet, this detrimental effect would manifest itself still more.

If no thermometers are provided how can we determine the approximate temperature of the returning gas?

In the absence of more accurate means for determining the temperature of the returning ammonia gas, the "frost line" has been forced into service to give some indication of such temperatures. The formation of frost on the outside of a pipe containing cold ammonia gas indicates that the heat from the outside atmosphere is absorbed with sufficient rapidity to reduce the temperature of the pipe to at least 32 degrees Fahrenheit, under which condition atmospheric moisture is precipitated.



Two types of ammonia couplings are shown. The difference between them is in the manner of their attachment to the pipe; the one to the left is a right and left coupling and can only be used where the ends of the pipe can be sprung apart to the distance A, while in the one to the right A is considerably less than the space between the pipes. The soft packing R in both cases is alike, but B, which is the total length of the coupling, requires considerably more space in the former.

Is the frost test a reliable one?

Since the formation of frost on an ammonia pipe is influenced by the room temperature, it cannot be an ideal means of judging temperature. Where entrained liquid ammonia is present to evaporate and absorb heat rapidly, the general appearance of the frost, or the way one's wet finger sticks to the pipe, may give some slight indication of the action taking place inside.

How can the condition of the ammonia vapor returning to the compressor be determined?

The condition of the ammonia vapor as regards saturation may best be arrived at through thermometers inserted in mercury wells in the suction and discharge lines near the compressor. Tables of "properties of saturated ammonia" indicate the temperatures at which the vapors should return to the machine under different conditions of back pressure and saturation.

If the last trace of the liquid ammonia is evaporated before the vapors reach the compressor, there is likely to be considerable superheating, i. e., the temperature of the vapor entering the compressor is likely to be several degrees higher than that shown by the tables to correspond to the back pressure carried. This condition results in a considerable loss of efficiency and should not be allowed to continue.

Where low temperatures are carried the return gas may be so far below 32 degrees Fahrenheit that the same rise in temperature that would ordinarily completely change the appearance of the return line if it took place at a higher temperature would not affect the frosted line at all, as far as outward appearances are concerned.

Is it advisable to allow the return pipe to be frost covered?

The frosting of the return pipe is an indication that the ammonia gas therein is taking up heat from the surrounding atmosphere, and this heat will have to be disposed of in the condenser coils. If, then, a certain amount of the heat in the returning ammonia gas has its origin in the engine room, where its absorption is manifested by frost in the return line to the compressor, it is evident that the frosting of the line costs energy to drive the compressor and that this energy costs coal, labor, and, finally, money. The return lines to compressors should be effectively insulated to reduce this loss.

But has not the returned gas performed its function ?

Nothing is more erroneous than the argument that because the returning gas has passed the rooms that it is sent out to cool, there will be no loss by heat absorption through exposed, uncovered cold pipes. As before stated any heat brought into the system from any other source than the substances to be cooled causes extra work for the machine, and such work is an economic loss.

Featherstone globe valve for ammonia.

Why is the insulation of the return ammonia pipe in the engine room very important ?

Heat absorbed by the refrigerating system out of the engine room is a double loss, for to attempt the cooling off of an engine room means more rapid radiation of heat from the steam pipes, and then to throw this heat in the shape of extra work upon the compressor may be termed imposing an extra load upon the machine.

What may be done to reduce the compression temperature in a dry compressor?

It is a common practice to carry the frost back to the inlet valve of the compressor, or to allow it to extend slightly beyond this. The gas in such a case is at a fairly low temperature at the start of the compression stroke, and will, therefore, not heat.

Angle valve for ammonia with four bolt flanges.

What is understood by carrying the frost back?

If we allow the return gas from the expansion coils to reach the compressor at or slightly below the freezing temperature we call this phenomenon "carrying the frost back to the compressor." If the gas reaches the compressor above the freezing temperature we refer to it as "allowing the frost to fall back."

Is it good practice to carry the frost back?

The condition generally accepted as most efficient is to carry the frost back to the inlet valve without allowing it to extend beyond the same, nor to fall back to any great extent.

May a dry compressor be run wet?

If we carry the frost back beyond the inlet valve, the indications are that the vapor contains a considerable amount of liquid which is still under the process of vaporization. The percentage of this liquid, generally consisting of minute drops, may be so great that its vaporization will extend well into the compression stroke, thus having the same effect as if it were injected, namely, taking up part of the heat of compression for its vaporization. The action of the compressor, therefore, approaches that of a wet compressor. If the frost is carried completely over the cylinder so that the water jacket has a layer of ice on its surface, it can be assumed that a portion of liquid ammonia is injected on each stroke.

Is it possible to obtain such extreme conditions?

It is possible, with extremely cold condenser water to have compression occur under these conditions without normal wet compression in the strict sense of the word. However, such temperatures of condenser water would be very unusual.

Does the speed affect the efficiency of the compressor?

The efficiency of a compressor is a function not only of temperatures but also of speed. The result is that the operating engineer should attempt to get a maximum speed out of his compressor with minimum steam consumption and minimum temperatures on the ammonia gauges.

How may we sum up what we have discussed in the preceding questions?

Available refrigeration is in every case directly proportional to the work done and hence the speed, if the pressures are the

same in the two cases, and it is the accepted opinion that ammonia compressors operate best under normal condenser-water temperatures when the frost is carried back on the suction pipe to within a few inches of the inlet valve of the compressor and the attempt made to speed up the compressor to the extent that the water jacket gets fairly hot. The frost will invariably slide in one direction or the other without regular attention, but it represents undoubtedly the point of maximum efficiency in the operation of the plant.

Does the "wet" compression system require some changes in other parts of the plant?

If you should change your compressor from working wet compression to working dry compression, you would find you would not get as much ice as you did before, unless you went further, and kept your evaporating coils working under wet compression conditions,—that is, kept the evaporating surfaces wet all the time. This you could do by putting in what is called the flooded system.

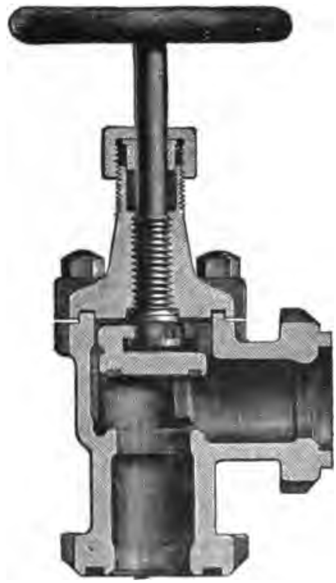
What would be the advantage of this?

By making this addition to your plant, as well as changing the operation of your compressors to the dry compression conditions you can get from 20 to 25 per cent. more ice out of your freezing system, but you would not be able to do this extra work unless you had ample condensers to condense the extra ammonia which the increased capacity made it necessary to be handled. Compressors should not be operated under dry compression conditions, without a knowledge of what is necessary to do to the balance of the plant.

Why do the needles on ammonia gauges sometimes show excessive vibration?

The cause of the excessive vibration of the pointers or needles on ammonia gauges is that the gauge valves open too

wide and the vibrations of the stroke of the compressor act directly upon the gauge springs and cause them to vibrate with each discharge of the compressor. To cure this evil shut the gauge valves tight and then open the same gradually until the gauge pointers or needles show a very slight vibration or motion, the small opening will prevent the pulsation of every stroke of the compressor being brought heavily upon the gauge spring.



A cross-section of an angle valve for ammonia with detachable disk.

Is it desirable to test occasionally the gauges ?

It is necessary that they should be kept in good order and condition.

Where should gauges be placed ?

About 12 inches above the level of one's eyes, they can there be easily seen and are accessible for cleaning, and should be indicated according to their purpose.

Why should a high back pressure be carried on a compression plant ?

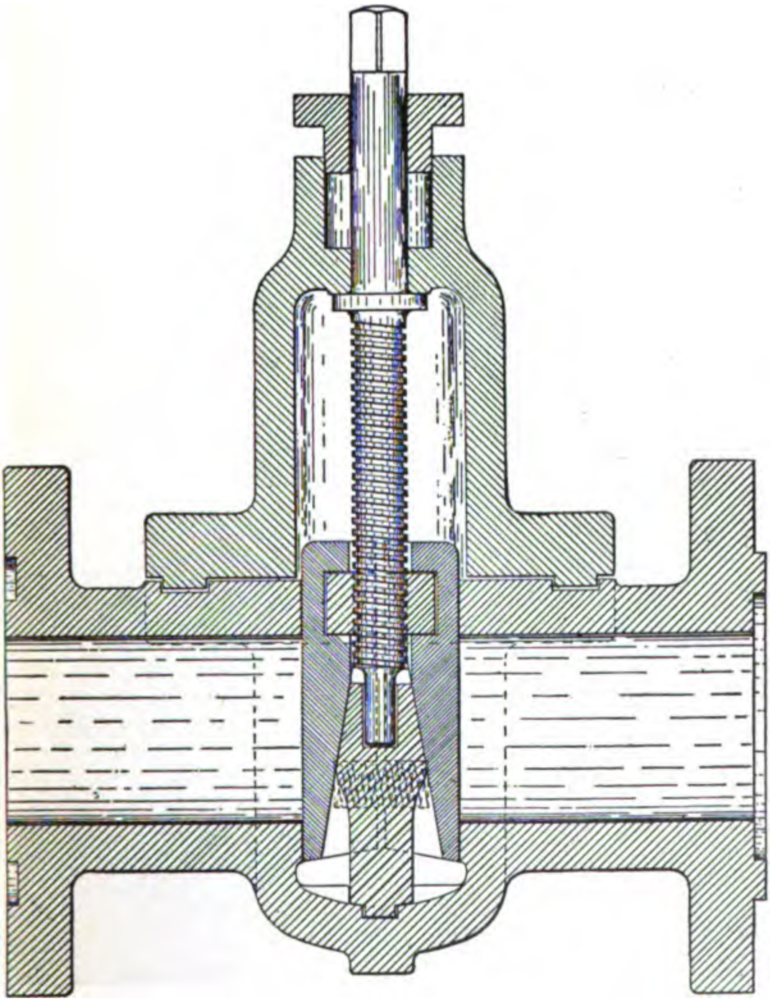
A compressor operates more efficiently at a high pressure, and does its work better the more gas it can collect per stroke and the higher the pressure. Hence, the pressure on the suction side of a compressor is allowed to rise until the ammonia boils at a temperature just sufficient to produce the liquid refrigeration. Thus, in ice-making the temperature is about 10 degrees above zero and the pressure for this is 23.64 pounds gauge pressure; that is, 38.34 pounds absolute pressure. By these means the amount of ammonia gas which goes into the compressor per stroke and the amount of ammonia liquid produced, and therefore able to be evaporated, increases with the suction pressure. Hence, the milder the refrigeration required the more efficient is the refrigerating plant.

How is the efficiency of the plant varied ?

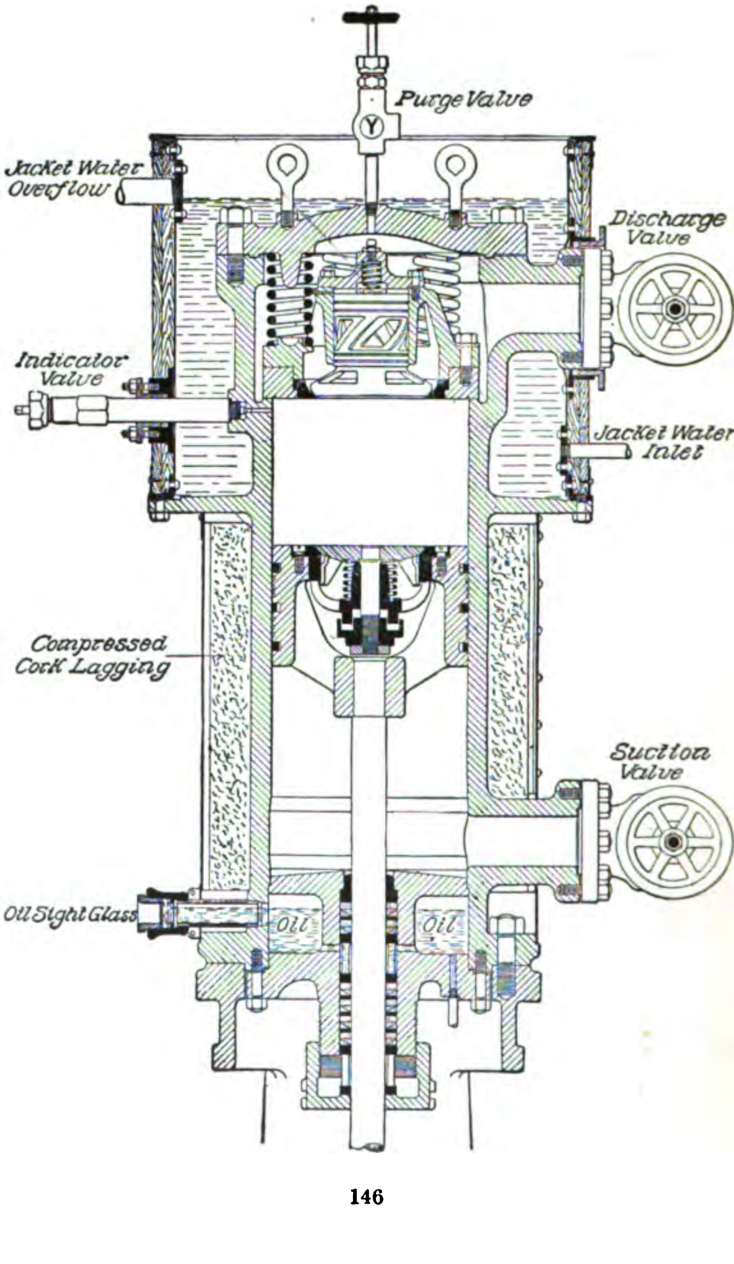
In order to make a room colder or produce more ice in a given time, the suction pressure is lowered, or the feed valve of the ammonia liquid is more completely closed, allowing less liquid to enter the evaporating or cooling coils, and therefore, keeping the pressure of the vapor less. This explains the main details and principles back of the operation of an ammonia compression plant.

Does the liquid entering the evaporating coils determine the full refrigerating effect ?

To determine the refrigerating effect produced by the evaporation of one pound of liquid ammonia at a given back pressure, a deduction must be made from the latent heat of evaporation at that pressure for the work required to cool the ammonia itself from the temperature at which it enters the evaporating coils to the temperature at which the evaporation takes place.



The Linde ammonia gate valve. This valve allows a perfectly straight passage to the flow of the gas. The gate is made in two halves which are separated by a wedge when the valve is shut.



Purge Valve
Jacket Water Overflow
Discharge Valve
Indicator Valve
Jacket Water Inlet
Compressed Cork Lagging
Suction Valve
Oil Sight Glass
Oil
Oil

The York Compressor.

The illustration on the opposite page is the modern York compressor of the single acting false head type. The false head consists of a casting containing the discharge valve at the top of the cylinder ; the head is held to a ground seat by means of extra heavy springs, which keep the head permanently against the pressure ; if, however, a broken valve part should be lodged between the piston and the cylinder head the springs would yield to the extra pressure and no damage would result.

The suction valve is contained in the piston which allows the use of an extra large valve.

It will be noticed that only the upper part of the cylinder has a water jacket, while the lower part is insulated. As the gas enters the cylinder its temperature is considerably below that of the water obtainable for jacket purposes, and, therefore, by keeping the cylinder insulated there is no tendency for the gas to take up heat from the water jacket. But at such a point in the stroke where the heat of compression has reached a temperature sufficiently high to be taken up by water at normal temperature, the waterjacket begins. Any heat taken up from the water jacket would tend to raise the temperature of the gas so much more at the end of the stroke, and thus more power would be consumed.

The stuffing box is surrounded by an oil well ; the oil level may be observed through the oil sight glass as shown in the illustration.

The stuffing box is of the Linde type with alternating soft packing and metal rings.

In starting or shutting down the compressor what points should be carefully looked after ?

Don't start the compressor without knowing the water is running freely over the ammonia condenser, and that every valve is open on the high pressure side, right down to the expansion valve.

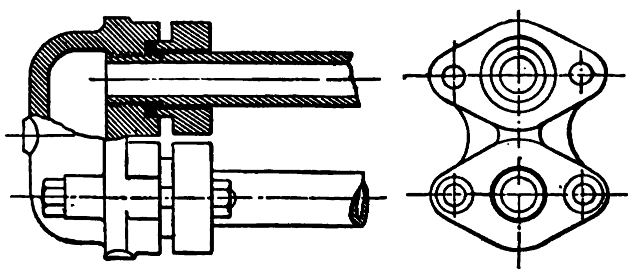
Don't pump a vacuum unnecessarily. Open the suction valve as soon as the engine will turn over the centers, and open the expansion valve as soon as the gauge indicates a pressure a little below the regular suction pressure.

Don't stop the compressor until the expansion valve has been shut and the suction pressure pumped down to within a few pounds of zero.

If the compressor is going to stand for an hour or more, shut the suction valve and tighten the piston rod packing. Be sure to slack off the packing when starting up.

If a charge is not working satisfactorily how should a sample be taken for testing ?

A common practice is to draw from the lowest point of the expansion coils, but as whatever impurities are in the system are bound to settle at or very near this point a test sample drawn there will show impurities in almost every case, even when the ammonia is in circulation and doing work in much better shape than the sample would indicate. It is a better plan to draw the sample either from the liquid receiver or from the charging valve as this would show something definite as to the amount of impurities in the system in general, and not the condition at a point where local trouble is almost certain to be in evidence.

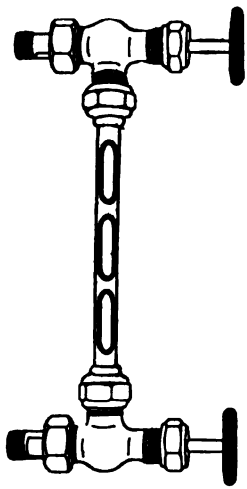


Section of condenser bend with screw glands and nuts.

How can you tell if your charge is insufficient ?

By trying the gauge valves on the glass gauge of your liquid receiver, if you have such a gauge (and you should have one). In the absence of a proper glass gauge the shortage can be detected by two positive indications : First, the liquid pipe between the liquid receiver and the expansion valve will become warm through blowing warm gas from the condenser to the expansion valve, which will also result in the temperature of the brine in the freezing tank running up. Second, the warm gas blowing from the condenser to the expansion valve will give

a distinct whistling sound, particularly at the expansion valve, while if there is sufficient liquid in the system the sound will be a low gurgle, indicating that liquid instead of gas is flowing through the liquid pipe. It may also be shown by a fluctuating pressure, variation of temperature in the discharge pipe, and by a rough action of the compressor valves which shows that the supply of ammonia and the consequent resistance varies.



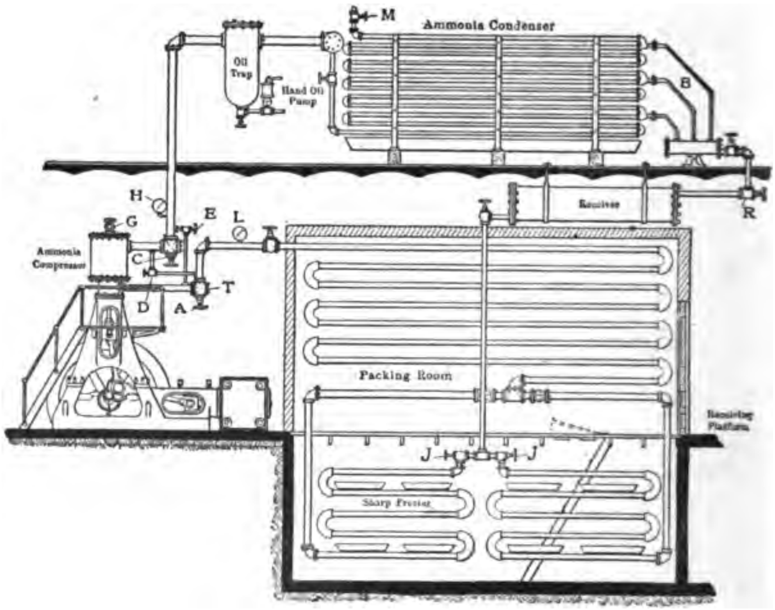
This ammonia gauge glass is protected by a tube cut out at intervals to show the liquid level.

What must be carefully provided for in the way of piping?

Not only should the joints be made tight but ample provision must be made for contraction and expansion. It is desirable too that it should be arranged so that a length or section may be removed, if necessary, for cleaning or repairs.

Describe a good method of pumping out for repairs ?

To illustrate the manner in which the ammonia is gotten out of the way, the sketch shown gives an outline of the piping in a fish freezer. Only one single-acting cylinder is shown. The same



This cut shows a more complete illustration of a refrigerating plant using the direct expansion system, which circulates the ammonia directly through the refrigerating coils. The ammonia is first circulated through a sharp freezer where a very low temperature is required, and from there it passes through coils in the packing room before returning to the compressor.
The pipe leading from the compressor to the condenser is provided with an oil trap which intercepts any lubricating oil that may escape from the compressor.

idea will apply to double-acting compressors if we remember that each end of the cylinder is single-acting.

We will assume that it is desired to take the cylinder head off the compressor shown in the sketch. If something is broken

inside and it is not possible to have the machine turn over, the valves "A," "C" and "E" should be shut, and valve "D" opened. This will put the discharge side of the cylinder in communication with the low side, and the pressure in the top of the cylinder will be equalized with that in the low side. Then close the by-pass valve "D" and open the cylinder-purge valve "G," which will allow the ammonia remaining in the cylinder to escape to the atmosphere. As it is only at the pressure of the low side it will take but a few seconds to blow off.

When the compressor is in a poorly ventilated room, the purge valve "G" should be connected to a piece of hose, the other end being held under the surface of the water in the cylinder jackets. The hose should not be held under the water too long or all the ammonia will be absorbed by the water ; this will leave a vacuum in the compressor cylinder, and the water will be forced into the cylinder. It is quite a job to sponge out this water in the pipes and ports.

Is it possible to pump all the ammonia out of the compressor that is doing the pumping ?

If the compressor can be turned over, the quickest way is to leave the valves as before ; "A," "C" and "E" closed and valve "D" open. Then by giving the machine a few turns all the ammonia will be pumped out of the bottom of the cylinder and the suction pipe up to the stop valve "A." Valve "D" is then closed and the purge valve "G" opened. By using this method only about one-third as much ammonia is wasted as when the whole cylinderful is blown out, as there is only the small amount of gas above the discharge valve to be blown out.

When it is desired to open up the low side, the expansion valves "J J" are closed and the ammonia pumped up to the high side by the compressor in regular operation.

To pump an air pressure on the low side with the ammonia in the high side, valves "A," "C" and "E" are closed and valve "D" is open. The side bonnet "T" or other flanges are opened

and the compressor pumps the air through "T" into the cylinder, and thence through by-pass "D" into the low side.

To pump the air out of the low side with the ammonia stored in the high side, valves "C," "D" and "E" are closed and valves "A" and "G" are opened.

Is pumping out the high pressure side more difficult than the low pressure ?

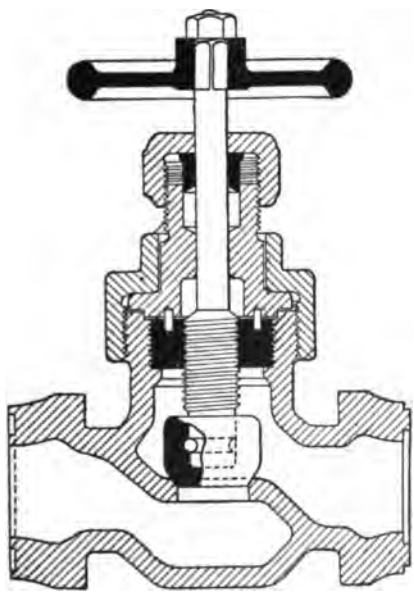
The pumping out of the high-pressure side of the system, including the condensers, the pressure tank and the liquid tank, is a slightly more complicated affair than that of the low-pressure side. It is accomplished by means of a pair of by-passes between the main suction and the main discharge lines, as shown on page 150. By means of these by-passes the action of the compressor can be reversed, so that the suction becomes the discharge and the discharge the suction line. Ordinarily, the by-pass valves "D" and "E" are kept closed, and the main line valves "A" and "C" open, so that the gas returning to the machine through the main suction line would pass through the main suction valve "A," through the compressor and out the main discharge line through main discharge valve "C."

How is it done ?

First open the expansion valves "J ·J," wide open; this will let all the liquid ammonia run into the low-pressure coils. While the pressure is equalizing in the high and low sides the machine valves can be adjusted. All the cylinder stop valves, as "A" and "C," are closed. The by-pass valves "D" and "E" are opened. Reference to the sketch shows that there is a clear passage from the discharge side through by-pass "E," into the bottom of the cylinder, and when the machine is in operation the gas is discharged through by-pass "D," into the low or suction side. This reverses the compressor.

The reason for equalizing with the expansion valves "J J," instead of through the by-passes, is to get all the liquid ammonia into the low side before starting to pump out.

When the pressure is equal on the gauges "H" and "L," shut all the expansion valves "J J" and start the compressor. It will take all the ammonia out of the high side and discharge it through by-pass "D" into the low side. The cold parts of the

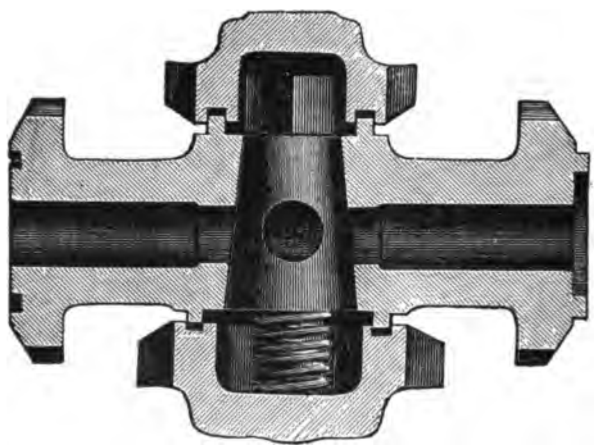


This valve is devised for repacking the stem with the pressure on, by unscrewing the stem until the beveled back of the enlarged part of the spindle comes up against the beveled seat formed on the bonnet.

low side, such as the ice on the coils and the air in the freezers, will act as a condenser, and the ammonia will liquefy and be carried away. If there is not an overcharge in the plant, and no foul gas, the pressure in the low side, when it contains the entire charge of ammonia, will not rise above that pressure due to the temperature of the coldest part of the low side.

How must the machine be operated in pumping out ?

In pumping out the high-pressure or discharge side, the machine must be run very slowly, in order to give the gas time to pass through the small by-pass lines. In this operation valves "D" and "E" are open and valves "A" and "C" are closed, so that the suction is cut off at "A," but continues through valve "E" to the former discharge line and the discharge cut-off at "C," continues through valve "D" to the former suction line.

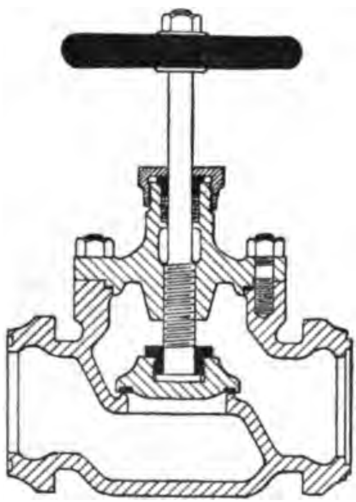


This is a section of an old type De La Vergne expansion cock with safety bonnet. After the proper adjustment has been obtained the bonnet is bolted over the square of the plug thus preventing the danger of leakage.

When the pressure on the high-pressure gauge is down around 25 inches of vacuum the machine can be stopped and by-pass valve "D" closed, to keep the pressure of the low side away from the cylinder. Then close valve "E" and give the discharge stop valve "C" a turn open. When the small amount of gas at

back pressure that is above the discharge valves has run back into the vacuum of the high side, the stop valve "C" is closed and a vacuum is formed on the whole of the compressor cylinders, and they can be opened up without any fear of escaping ammonia.

Next to the compressors, the high side has to be opened up more frequently than the other parts.

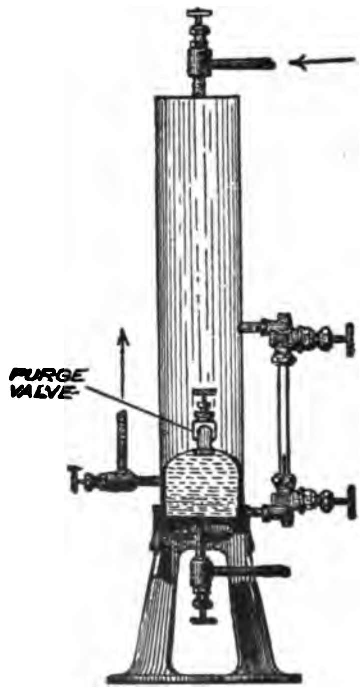


A section of a plain ammonia valve with flanged bonnet and soft packed disk. The packing in the disk can be renewed when worn out.

Is there any difficulty encountered in pumping out the low pressure side ?

In the style of plant shown on page 150 it is easier to pump out the high side than the low side, because the liquid ammonia will lie in the coils of the sharp freezers and the storage rooms. Pumping a vacuum on the coils does not boil the ammonia ; it takes heat to boil the liquid whether it is

under a pressure or in a vacuum. After a vacuum has been pumped on the low side of such a plant and the machine stopped, the pressure will gradually rise on the low-pressure gauge, on account of the liquid ammonia in the coldest coils slowly boiling into gas. To get all the ammonia out of the low side, a vacuum



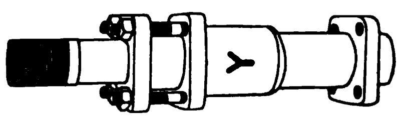
This illustration is an oil separator, as is often connected to the discharge of a compressor. It collects the oil which may accumulate in the pipe and also will act as a pressure tank. The oil may be drawn off periodically through the bottom cock and any foul gas may be blown off by means of the purge valve.

would have to be pumped a number of times so as to take out all the ammonia gas. It might take a couple of hours for the ammonia to all boil out of the cold rooms, so when it is required to pump all the ammonia with one machine out of itself, it is

always better to reverse the machine and pump out the high side, because all of its parts are warm and the warm rooms and piping will boil out the ammonia as fast as the compressor can take it away.

Why do some of the small collecting pipes need occasional renewal?

A common thing is to have to renew some of the ½-inch liquid-collecting pipes shown at "B." The pipes are small and the fitters do not take much care in their work, as the pipes can be pulled or bent into position for the final connection and they soon show breaks at the point where they are screwed into the bend or header. If the break is noticed in time so that the ammonia can be pumped out, the same process is gone through



An expansion joint of the type illustrated here should be placed in long straight pipes. It consists of a sleeve which fits into a stuffing box provided with rubber composition packing.

as already described in pumping out the cylinders, which may be summed up as follows: Equalize and drain the liquid into the low side through the expansion valves "J J," and then shut these valves. If the valve "R" on the receiver is known to be tight it can be closed and then pump back from this valve instead of the expansion valves. To pump out the high side, compressor valves "A" and "C" are shut and "D" and "E" are open. When as good a vacuum is obtained on gauge "H" as the machine will give, stop the compressor and close by-pass valve "E." Then a vacuum will be had on the compression side from the machine to the receiver inlet valve "R," or whatever valves on the main liquid line that were closed. It is then safe to disconnect any part of the high side between these two points.

Why is it sometimes difficult to start a large compressor ?

It is sometimes impossible to start a compressor when there are other compressors running, as the load is so heavy that the engine cannot turn over the center the first time. This is where the by-pass piping comes in very handy, and the operation is known as starting on the by-pass. While the machine is standing still, valves "C" and "E" are closed and valves "D" and "A," opened. This equalizes the pressure, top and bottom, of the compressor piston and the engine has only the friction load to start. As soon as the machine is turning over under control valve "C" is opened. While opening the valve "C" the head pressure is rushing through valve "D" into the low side ; then close valve "D" as soon as the discharge valve "C" is open. Valve "C" must always be opened before valve "D" is closed, or a cylinder head will be blown out. Next open valve "A" very slowly, the man at the throttle giving the engine the steam as the suction valve "C" is opened.

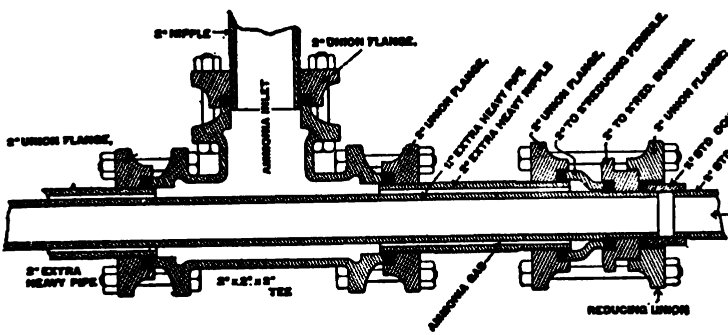
The by-pass valve "D" should be closed as soon as the discharge valve is open about two turns.

How may newly repaired parts be tested ?

An air pressure should be pumped on the part repaired to make sure everything is tight. To pump an air pressure on the high side with the ammonia compressor, when the ammonia is stored in the low side : Valves "A," "D" and "E" are closed to hold the ammonia in the low side, and Valve "C" is opened. The flanges can be open on the side bonnets "T" to let air into the compressor. If the suction valves have no side bonnets, the flanges can be opened on the by-pass line between valve "E" and the suction line. When an air inlet has been made the machine is started, when it will pump an air pressure on the high side. The new work is then inspected ; all the joints should be painted with soapsuds, and any bubbles that increase in size will indicate a leak at that point.

How do we rid the high side of this air ?

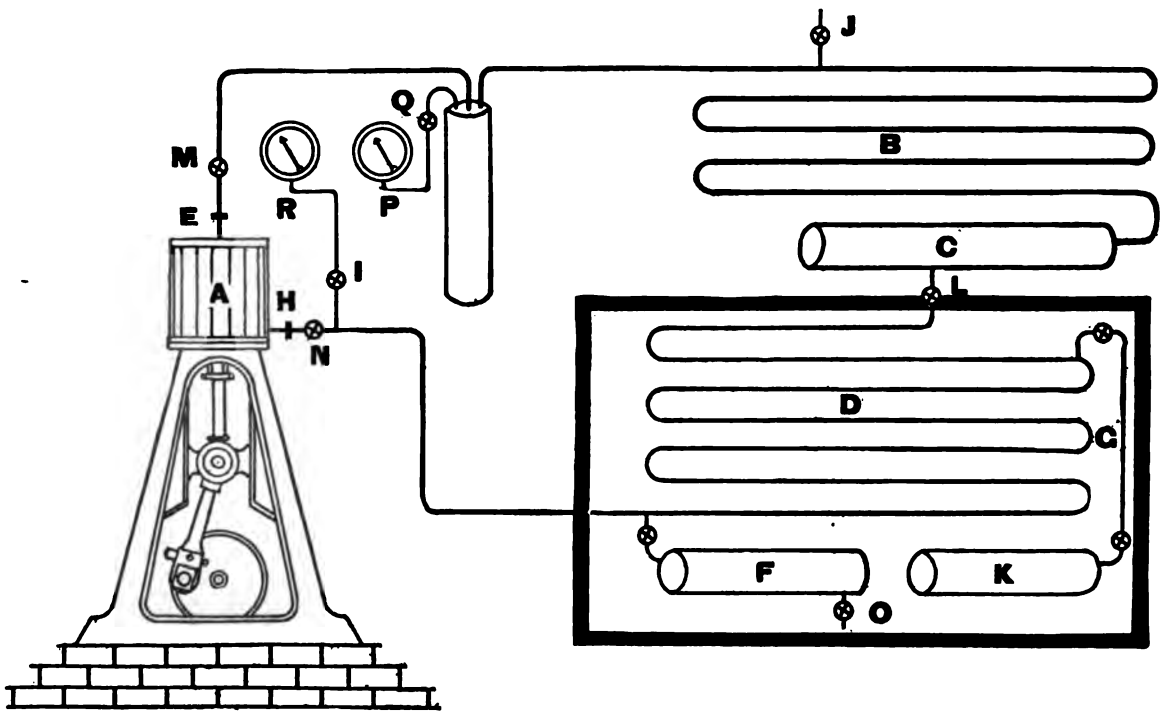
If everything is tight the air is allowed to escape through the condenser purge valve "M." This leaves the whole high side full of air at atmospheric pressure that must be pumped out before the ammonia can be circulated. To get this air out, the compressor valve "C," purge valve "M" and bonnet "T" are closed ; valves "E" and "G" are opened. With this arrangement the air is drawn from the high side through valve "E" and discharged into the atmosphere through the cylinder purge valve "G." When a good vacuum shows on the high-side gauge the machine is stopped, the purge valve "G" closed, and the ammonia allowed to equalize in the system through the compressor by opening the cylinder stop valves before valve "R" is opened.



Cross section showing water connection to double pipe condenser.

Why should care be taken in starting up when the liquid is all on the low side ?

Great care should be taken when starting up after storing all the liquid in the low side, as the liquid easily gets into the cylinders and acts the same as water.



This system is explained in detail on page 163. The tank shown at F will collect most of the impurities in the low pressure system, which may be drawn off at O after closing the connection between the tank and the pipe line.

How may leaks be avoided?

If the liquid were allowed to stay in the high side and be pumped out backward, the evaporation of the liquid would heavily frost all the high side, and as it is usually hot, the contraction would probably start a number of leaks, and once a leak starts, when pumping out, it will keep on leaking when the high pressure is put on again, because the leaking liquid ammonia will cool the iron around the leak and prevent its taking up with the heat of the high side. When the high side is properly erected without any pockets, the liquid will all drain into the low side and the high side may be pumped out without any frost appearing on any part of it.

Why must the gaskets be of special quality?

The gaskets used in a refrigerating system should be exceptionally good and elastic, as they must withstand the action of ammonia. The tendency of ammonia is to soften and swell the rubber, and if portions of this gasket become detached in the pipe they may go through and clog the expansion valve and cause trouble. A proper rubber compound is far more satisfactory than pure rubber. Some designers have constructed flange joints made in such a way that the rubber can hardly come in direct contact with the ammonia. The extreme changes of temperature in a cooling system make it necessary to have an elastic gasket, or to allow means for contraction and expansion loops in the line or expansion joints.

How are the joints made differently from steam joints?

The latter can be made tight by the use of red or white lead, but the former require to be screwed and packed in addition.

On pipes of ½-inch and less diameter, soldering is often resorted to. The threads of pipe and fitting should be well tinned and screwed together while hot, with a blow torch playing on the joint.

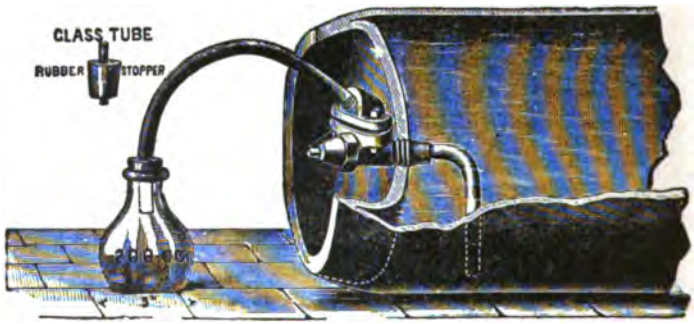
How should a compression plant be tested before starting up ?

By trying it with compressed air up to 500 pounds pressure, which can be done by working the compressor and leaving the suction valve open. Thick soap lather which may be smeared over the pipes will show bubbles of air if there are leaks.

The condenser and brine tanks being filled with water will also show bubbles of air if leaking. When the temperature and pressure are equalized all over the system the pressure gauge should remain stationary.

What should be done if leaks are suspected ?

They should be instantly traced, located, and mended.



To draw a test sample of ammonia, a bottle is connected to the drum as shown, and a small amount of ammonia drawn off and allowed to evaporate in the bottle. Any water contained in the liquid will remain in the bottle and the percentage may thus be determined. The ammonia should be evaporated through a small glass tube inserted in a rubber stopper.

How may leaks be repaired ?

Small ones may be closed by tin solder, or a cement made by mixing litharge with glycerine to a stiff paste, with this latter sheet rubber and a sheet iron sleeve clamped on should be used. Electric welding may be resorted to if conditions are favorable. If the leak is a serious one new coils or lengths of pipe must be put in.

If this test is satisfactory what is done next ?

By opening the proper valves and starting the pumps a vacuum is created in the machine, and then the vacuum gauge should remain perfectly at rest.

If a very low vacuum is not obtainable how does an engineer proceed ?

In this case, which shows that some air is left in the machine, it is advisable to charge the plant by degrees. If one half the necessary charge be put in the machine and fully circulated over the system most of the air will collect at the top of the condenser, and may be blown off by opening the cock which is placed there. After this is done one or two more instalments of ammonia will charge the plant fully.

If the vacuum is shown to be very good what is next done ?

The machine is ready for charging and the drum or cylinder of ammonia is connected to the charging valve. Before opening the valve on the ammonia flask the expansion valve between the ammonia receiver and the expander is closed. Now the compressor is kept running slowly with suction and discharge valves open and water running on the condenser.

Describe in full a common method of testing and charging a plant.

This system is complete within itself, that is, there are but three openings to the atmosphere. See cut on page 160.

The first of these is a charging connection for permitting ammonia gas to enter (G).

The second, on the top of the condensing system at its highest point (J), is for removing air which may, from time to time, enter while making changes in the ammonia system.

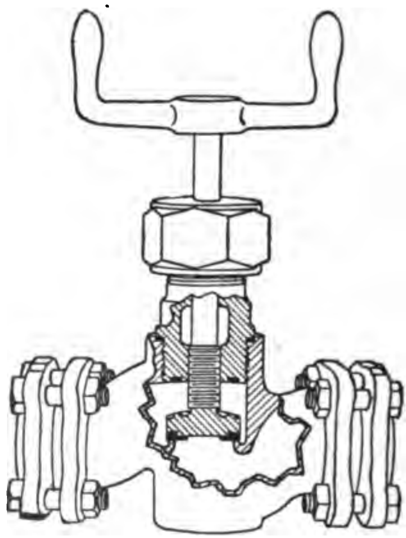
The third is at (F) the lowest point in the refrigerating pipes, usually lower than the gas pumps, and is for the removal of oil, water or dirt which may collect at this point.

What is the first step to be taken ?

On the completion of the plant, the connections at the discharge and suction side of the gas compressor should be opened and the engine and compressor run until they are in working order.

When the engine and compressors work smoothly, close up the flange connections on the discharge at E, also the gas valve at "N," leaving flanges at "H" open ; this allows the pumps to draw in air, and an air pressure to accumulate in the piping.

The object of this being to test joints for leaks.



Partial section of a quick opening ammonia valve. The disk of this valve is provided with a turned tip on the top face, which, when forced back against the gasket in the bottom of the bonnet makes it possible to repack the spindle with the pressure on.

If the system seems to be tight what is next to be done ?

If no leaks are found, pump air pressure to about 100 lbs. per square inch, then stop until the heat generated in the compression of the air, which will be about 150 degrees, has passed away.

While the engine is stopped, make a careful examination for leaks, as it is positively necessary to have tight pipe work, for the loss of ammonia gas means the loss of ability to do refrigerating.

After allowing the machine to lie still about one hour, start up again and pump up pressure to 200 lbs. per square inch, and again allow the machine to cool down. Continue this method of pumping pressures until you have a pressure of 500 lbs. per square inch, when the suction flange "H" should be bolted tight and the valve "N" opened. This will give you a pressure of, say 450 lbs., on all sides of the gas pump. At this time it will be found that the stuffing box leaks a large amount of air.

As soon as you definitely determine that all joints around the compressor are tight, shut off the suction and discharge valves "N" and "M" and allow the pressure to remain in the piping. The object of closing the two valves is to prevent the loss of air around the piston and stuffing box.

Will the air pressure remain constant?

The air pressure in the piping will fall as the air becomes cool, or falling from a temperature of 100 degrees to 70 degrees F. the pressure should fall about 25½ lbs. per square inch providing there are no leaks in the piping or joint.

If the compressor has been running very slowly the temperature may not rise perceptibly as the heat of compression will be carried off as fast as the compression takes place.

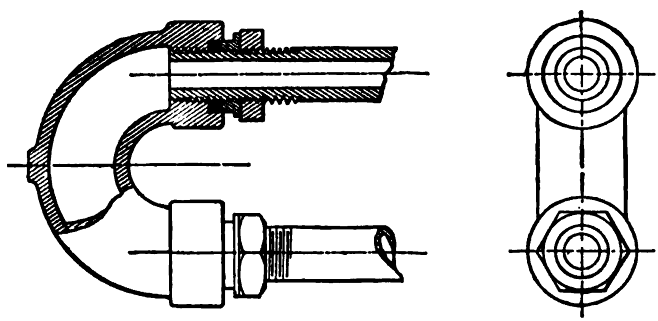
While pumping a pressure on the coils, the return pressure gauge "R" must be closed off at cock I. This gauge is what is known as a combination gauge, recording both pressure and vacuum; that is marking the condition from absolute pressure, which means the absence of atmospheric pressure.

The high pressure can be noted on the gauge "P," which is usually constructed to permit the indication of pressures as high as 500 to 600 lbs. per square inch.

What should be done if the system is found to be thoroughly tight ?

If the system is found to be tight, pump the air out of the piping. Close the cock "M" on the discharge side of the gas pump and open the flanges "E," which will permit the discharge of the air. Open the valve "N" on the suction side and permit the air pressure to discharge.

When the pressure is at atmosphere open the return pressure gauge "R" and close off the direct pressure gauge ; the reason for closing this last gauge is that it does not register below atmosphere and if it is not closed the interior mechanism of the gauge will be injured.


Solid return bend, screw joints.

Why is great care necessary in pumping out the air ?

Start the gas pumps and discharge the air at flange "E." Care must be taken in doing this, for if any oil is discharged with air, which comes out in a spray like a fog, and it should come in contact with the light of a candle or of gas, there would be a sharp explosion, caused by the carbon of the oil mixing with the oxygen of the air and other elements necessary to do much damage.

Having pumped the air from the pipes until the combination or back pressure gauge "R" registers 26 or 28 inches vacuum, which would mean the removal of at least 90 per cent. of the air in the plant, attach a shipping tank of ammonia, "K" to connection "G," and allow sufficient gas to enter to raise the pressure to atmosphere.

How fully is the air now disposed of ?

There is now 90 per cent. of ammonia gas mixed with 10 per cent. air. Close all connections, and pump the gas into pressure in the condenser and examine again for leaks.

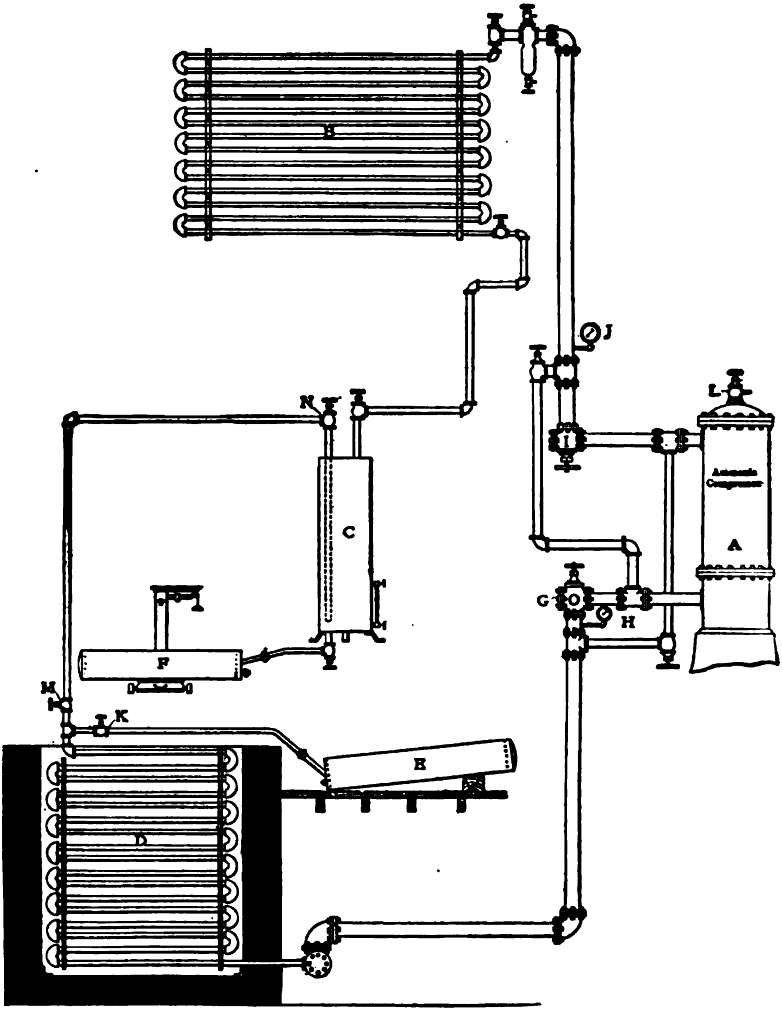
If the work so far is found to be all right, open flange "E," close cock "M" and pump this mixture of gas and air to the atmosphere until there is 26 or 28 inches of vacuum. This will leave 10 per cent. of the air and gas in the piping, but, as 90 per cent. of this is ammonia, the charge would only have one per cent. of air.

If the plant is found to be in proper condition what are three or four of the first things to be considered ?

The careful regulation of the expansion valve. The supply pipe to the condenser should not get warm. The temperature of the brine should be about 5° to 10° F. higher than the temperature corresponding to the indication of pressure gauge on refrigerator. The temperature of the cooling water should be from 10° to 20° F. below the temperature corresponding to the temperature in condenser coils.

What is a very common occurrence that the engineer may have to look out for ?

A failure of the supply of water entering the condenser and the compressor water jacket. For instance, in case of fire in the vicinity of the plant, the fire engines for a time may take all the supply from the mains. Again the supply is sometimes shut off to repair the pipes or to make new connections.



The above is a general outline of a compression plant showing the necessary detail to make clear the directions given for charging and discharging on page 169.

Describe in detail a method of charging and discharging a plant.

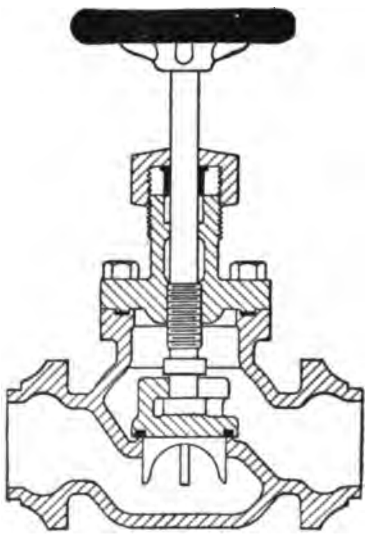
In the figure on page 168 is a sketch showing the principal parts of a refrigerating system that uses ammonia as a heat carrier, circulated by mechanical means. "A" is a single acting ammonia cylinder, "B" is the ammonia condenser, "C" is the liquid ammonia receiver and "D" is the brine tank and expansion piping. A drum of liquid ammonia connected to the system to charge the plant with ammonia is represented at "E," and "F" is a drum connected to the system to receive the ammonia when it is desired to empty the system. Assuming that the piping has all been erected as shown and that it is desired to test the system with air to see if everything is tight, at this time the drums "E" and "F" are not connected as shown, and the valves to them will be closed. The purge valves on the trap and compressor will also be closed.

Starting with valve "I," all the valves on the main line, to and from the condensers, will be open; those on the receiver and brine tank will also be opened, so that there will be a clear passage from the discharge valve "I," right around to the suction valve "O." The by-pass valves will be shut. Then shut the suction valve "O" and remove the side bonnet "G." This allows air to be drawn into the cylinder when the piston is moving. Then start the machine and run it until the low-pressure gauge "H" shows the pressure at which it is desired to make the low-side tight. This is usually about 150 pounds to the square inch. This pressure is also high enough to find most of the leaks on the high-side.

How are leaks detected in the piping?

When the low-side is made up of brine tanks it is usual to fill them with water while the air pressure is on the piping, then any leak will show by the air bubbles rising up through the water. The outside joints and flanges are gone over with soap

suds to find small leaks. It is usual to let the pressure stand on the system over night to see how much of it will leak out. When the low-side has been made tight the expansion valves "M" are closed and the air pressure on the entire high-side is run up until the high-pressure gauge "J" registers 300 pounds. At this pressure all of the high-side is made tight.



A section of an ammonia valve with detachable disk.

How is the air disposed of when the machine has been tested ?

After everything has been pronounced right the compressed air is allowed to escape through the purge valves on the trap and receiver, so that any loose scale and dirt will be kept away from the compressor. The system is now full of air at atmospheric pressure and this air must be removed before the ammonia is put in. To do this the purge valves that let the air out are closed. The expansion valves at "M" are opened again. The suction valve

"O" is opened and the valve bonnet "G" put on again. The discharge valve "I" is closed and the purge valve "L" is opened. The system is now the same as when it is circulating ammonia, with the exception of the discharge valve being closed and the cylinder purge valve open.

The compressor is now started and the air that the compressor takes out of the system is discharged through the open purge valve "L." If the suction valves of the compressor are well balanced against gravity, a vacuum of 30 inches can be obtained. When the high and low pressure gauges show as perfect a vacuum as the machine will pump, it is the usual practice to shut down the machine and see if the vacuum will remain in the system. This will usually be the case if it was tight under pressure.

The system is now ready to be charged with ammonia. To prepare the system for charging all the purge valves are closed, also the by-pass valves, and the expansion valves "M." If it is not possible to get the charging connection into the line as shown it can be put anywhere on the liquid line between valves "M" and "N." When charging the ammonia the valve "N" can be closed. Either one of these valves must be closed to hold back the liquid. All the other stop valves on the line must be open.

How is the cylinder of ammonia placed when connected with the machine ?

A drum of ammonia is then connected to the system as shown at "E." The back end is elevated as shown, as it lets the ammonia run out faster. If the drum was set level there would be about a pailful of liquid left in the bottom of the drum that would require an hour in which to boil out. In a small plant it is just as well to leave the drum level on the floor because the liquid has to be expanded into the system. It will be noticed that when the liquid ammonia is let into the system through the valve "K" it has to pass through the expansion piping shown

at "D." This will boil the liquid into a gas and it can, therefore, be fed faster into the system. As quick as the liquid turns into a gas it is taken by the compressor "A" and pumped through the ammonia condensers "B." The cold water running over these pipes will condense the ammonia gas into a liquid, and it will run from the condensers into the liquid receiver "C."

How do we know when the machine is fully charged ?

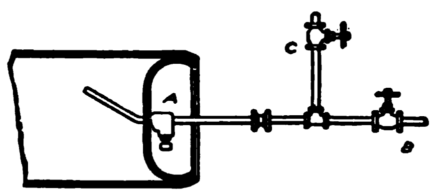
If there is a gauge glass on the liquid receiver it is quite easy to tell when there is enough ammonia in the system. It is only necessary to choke off the water on the ammonia condensers until the head pressure runs up to what it will be under full load, then the expansion valve "M" is opened until the desired back pressure is obtained. The head or condensing pressure will be about 15 pounds more than the pressure due to the temperature of the condensing water as it leaves the ammonia condensers. The back pressure will be the pressure due to 10 degrees Fahrenheit colder than the coldest brine or room. When the machine is running with these pressures there should be about six inches of liquid over the end of the outlet pipe shown by the dotted lines at "C."

How is it possible to tell the charging conditions by sound ?

In case of a plant without a gauge glass on the liquid ammonia receivers, it is possible to tell when there is enough ammonia in the system by the noise it makes when passing through the expansion valves "M." Ammonia liquid is like water, and it makes the same noise when running through a pipe. When there is not enough liquid ammonia in the system the gas blowing through the expansion valves "M" will make a noise like steam rushing through a pipe. It is only necessary to keep putting in liquid until this noise stops. The plant will then be fully charged and no more liquid will be required until the expansion valves commence to whistle again.

How isthe ammonia cylinder arranged when it becomes necessary to withdraw the charge from a machine ?

Sometimes it becomes necessary to take the ammonia out of a piping system and then the drums are connected as shown at "F." In this case the empty drum is set on a platform scale and connected in that position. The empty drum is then weighed and not more than 100 pounds of ammonia should be allowed to run into the drum, so as to leave room for expansion of the ammonia by heat. If the liquid receiver is in a warm room the empty drum should be covered with wet bags and ice laid on top of the bags. This will condense any vapor that may be formed in the piping or drum. Even with ice on the drum it is sometimes necessary to loosen up on the union between the



In the above illustration the cock marked A is a part of the shipping drum, the piping on the outside, with the cocks C and B, is attached for charging the drum.

receiver and drum to let out any dead vapor that refuses to condense. If it is a large plant that is being drawn, it is advisable to put in a vapor outlet between the receiver and drum. Then when it is noticed by the scale beam that the drum is not filling up, the purge valve on the bottom of the receiver is closed and the vapor outlet opened quickly, and as quickly shut. This lets the vapor out and the liquid will run right down. The piping from the receiver should pitch down to the drum and the drum should be placed with the drum valve stem above the pipe, but the receivers are usually so close to the floor that the only way the drum can be connected without pockets in the piping is by laying the drum valve stem and pipe level.

What precautions are necessary to insure a complete withdrawal of a charge ?

After the drum "F" is in position, the next thing is to get all the ammonia that is in the system into the receiver in liquid form. Valve "N" is first closed, and the expansion valves "M" are all opened, so that any liquid in the high pressure piping, between valve "N" and the expansion valves, can boil out. The machine is then started and run slowly, while the coldest water is allowed to flow over the condensers. As near a perfect vacuum as the machine will make should be pumped on the low side. The compressor may then be shut down with the water still running over the condensers, so as to condense as much of the ammonia as possible. If the vacuum remains on the low side it shows that all the ammonia has boiled out of the piping; when a pressure builds up on the low side it shows that liquid is lying in some cold part of the system, and the compressor must be run again to pump all the gas out.

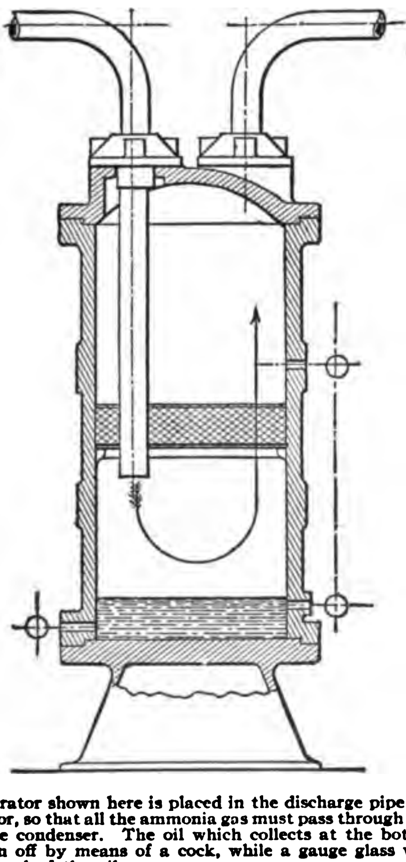
After the engineer has all the gas out of the low side, the bonnet "G" of the suction stop valve "O" is taken off and the compressor is run very slowly for a few minutes pumping air into the high side. The pressure on the high side should be run up 50 pounds higher than it was when the ammonia was being pumped out of the low side. The air is not condensable at that pressure and it fills up the high side and holds up the pressure high enough to let all the ammonia condense and flow down into the receiver, from which it can be run into drums.

Is a compression machine more economical than an absorption plant ?

The cost of coal : cost, quality and supply of water ; cost of labor, and many attendant circumstances must be taken into consideration before it can be determined which type of machine is more desirable in any particular place.

How does the oil trap sometimes make trouble ?

The pipe to the purge valve on the bottom fills up and refuses to clear when the valve is opened. A good plan is to put on another valve or cap on the end of the pipe and to put



The oil separator shown here is placed in the discharge pipe of the compressor, so that all the ammonia gas must pass through it on its way to the condenser. The oil which collects at the bottom can be drawn off by means of a cock, while a gauge glass will indicate the level of the oil.

on a hand oil pump. Then, a little kerosene can be pumped into the trap and the oil will come out with a rush.

Is there any danger to guard against when re-charging a plant with ammonia ?

If the shipping drum has been stored in one of the freezing rooms at a very low temperature, it is possible that the drum will become filled with liquid ammonia instead of being discharged into the system, as the pressure may be considerably below the pressure in the pipe through which it is charged.

An expans.on valve of the De La Vergne type. The disk is provided with a projection which fits a bore snugly. This projection is slotted to make the opening very gradual.

Explain how such a result may be brought about.

If the shipping drum has been kept in a room at 5° temperature, the pressure of the contents of that drum would be 19.46 pounds per square inch. If this drum is now connected to the high pressure side of the system it is obvious that the drum will fill with ammonia until there is no space left for gas.

What would be the result ?

As soon as the completely filled drum would be subjected to a higher temperature an explosion would be unavoidable.

What, in consideration of the danger, would be the right place to charge a system ?

At the low pressure side.

Would there be no danger when charging at the low pressure side ?

It is possible to have the shipping drum at a lower pressure than even the low pressure side, as the pressure may have been raised since the drum has been taken from the storage room. It is always advisable to allow the temperature of the drum to rise above that of the pipe to be charged, thus increasing its pressure.

Where is the best place to discharge the drum into the system ?

Close to the low pressure side of the expansion valve, as then we obtain the benefit of the cooling action of the liquid as it evaporates in the expansion coils. If we should discharge it into the suction pipe of the compressor we would lose all the benefit of the evaporation.

When the system is so arranged that it cannot be charged on the low pressure side, where should it be charged ?

It may be charged through a cock in the pipe leading from the condenser to the receiver, into the receiver directly, or preferably close ahead of the expansion valve.

If any of these last mentioned means must be employed what safeguard should be provided ?

A reliable check valve should be placed in the charging pipe to prevent liquid from flowing back into the drum.

If we charge through the receiver will we lose the benefit of the evaporation of the contents of the drum ?

No, the liquid will have to pass through the expansion valve and coils with the rest of the liquid.

What would be the benefit from the evaporation of the contents of a 100 pound drum when passing through the expansion coils ?

A refrigerating effect equal to the melting of 300 to 350 pounds of ice.

If we can charge at the low pressure side of the expansion valve, would a check valve in the charging pipe be advisable ?

As stated before, there is a possibility of the ammonia backing up into the shipping drum even at the low pressure side, although the danger is much less ; however, as long as there is the remotest possibility of danger, the price of a check valve should not be regarded as an unnecessary expense.

Would the ordinary check valve, such as used on steam and water piping, be sufficient ?

Such check valves are entirely or partially made of brass, which is unsuitable for ammonia ; also the pipe connections on an ordinary check valve could not be made tight enough for ammonia.

When discharging a drum into the system what other precautions should be taken ?

It should be watched, and removed as soon as it is empty, for even when check valves are placed in the charging pipe, there is a possibility of their leaking.

How can we tell when the drum is empty ?

When the charging is done into the suction of the compressor, there is no danger of the tank being refilled from the pipe, for even if the suction pipe is frost covered, the temperature of the engine room would keep the drum at such a temperature that no liquid could enter without evaporating immediately. Therefore, if we notice the frost on the outside of the drum disappearing, we may safely consider all the liquid to have evaporated out of the drum, and even if the drum is not removed immediately no harm would result.

Is it necessary to take greater precautions when charging at any other part of the system?

When charging at the high pressure side the drum should be removed as soon as the frost disappears, to prevent any ammonia from running back into it, and it would be a good plan to have the charging valve so arranged that the charging drum would be located so that its temperature would be raised a few degrees above that of the rest of the high pressure piping. When charging at the low side of the expansion valve the same signs will indicate that the drum is empty, that is, the frost will appear and then disappear, and the drum should be removed.

What other safeguard should be taken?

The cylinder should be weighed before attaching to the charging valve, and the contents, as recorded on the tag, noted; then it should again be weighed after being discharged, and if the difference coincides with the record on the tag, the cylinder is empty. Such a comparison is also good when drawing the charge out of the system.

How should the cylinder be placed?

With the closed end elevated a few inches above the valve end, and with the internal tube turned downward.

What is usually the contents of an ammonia shipping cylinder?

About 100 pounds to 110 pounds.

How much gas space should be left in the cylinder?

About one-third of its entire capacity is good practice.

What amount of anhydrous ammonia is needed in a plant?

Say the whole space of the condenser to be filled with ammonia vapor at 165 pounds pressure, the ammonia expansion pipes at 20 pounds pressure, and 25 pounds liquid ammonia for every cubic foot of liquid receiver capacity.

How much ammonia will it take to charge a compression plant?

While there is no absolutely fixed rule the following may be considered in line with the average practice:

Tons of ice per 24 hours:					
5	10	15	25	50	100
Pounds ammonia:					
100	250	500	1000	2000	4000

This expansion valve is of the same type as the one on page 176, but the disk and spindle are made in one piece.

How is it often estimated?

Allowing one-third of a pound of ammonia per lineal foot of 2-inch pipe. Thus a 25 ton ice plant having about 5000 feet 2-inch pipe would take 1666 pounds ammonia, while a direct expansion plant of 25 tons refrigerating capacity having 2000 feet of 2-inch pipe would require about 700 pounds.

Describe a method for connecting the shipping drum.

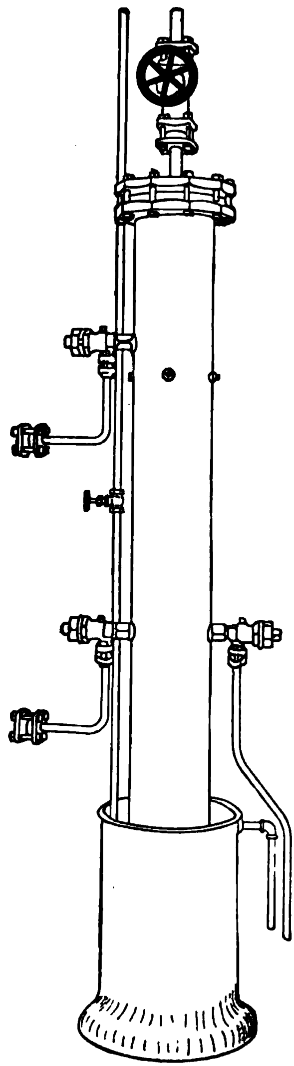
To draw off the charge, or to put the ammonia into the shipping drums, the drum should be turned with the internal tube pointing up, as in the figure on page 173, and this may be done by seeing that the valve stem, or the hole for connecting the charging pipe, is turned down.

By means of nipples or pieces of ammonia pipe joined together by a union, the valve "A" is connected to one run of a tee, ammonia piping being screwed into the other run and into the branch of the tee, and a good valve placed in each of the two branch pipes. One of the branches is connected to the liquid or pressure side of the system, and the other to the suction side or to the expansion valve. Suppose that valve "C" is connected to the liquid receiver, it will first be closed, as will also the valve at the receiver, and the valve "B" will be opened. Thus the expansion coils and the drum are exhausted, after which the valve "B" is closed.

How is the king valve managed ?

The king valve at the receiver is now opened wide and the valve "C" is opened quickly to cause a sudden rush of ammonia to the drum which is placed on a scale platform. After the charge of ammonia is in the drum, the weight on the scale arm is moved out until the arm is in balance. This done, the king valve at the receiver and the valve "C" are closed and the machine run until the expansion coils are pumped out to zero pressure, at which time the valve "B" is opened so as to draw off the gas in the top of the drum, through the internal up-turned pipe.

When all the gas has been drawn off, the ammonia in the drum may be heard to boil and the arm of the scale will drop. At this point the valve "B" is closed and the charging process repeated as many times as may be necessary to put the required weight of ammonia into the drum.



An ammonia regenerator for distilling the ammonia periodically. The liquid is charged from the receiver into the central drum and the tank at the foot is filled with water which is heated by steam; the ammonia is thus slowly evaporated and returned to the system.

What should be done after the charge is taken out of the machine ?

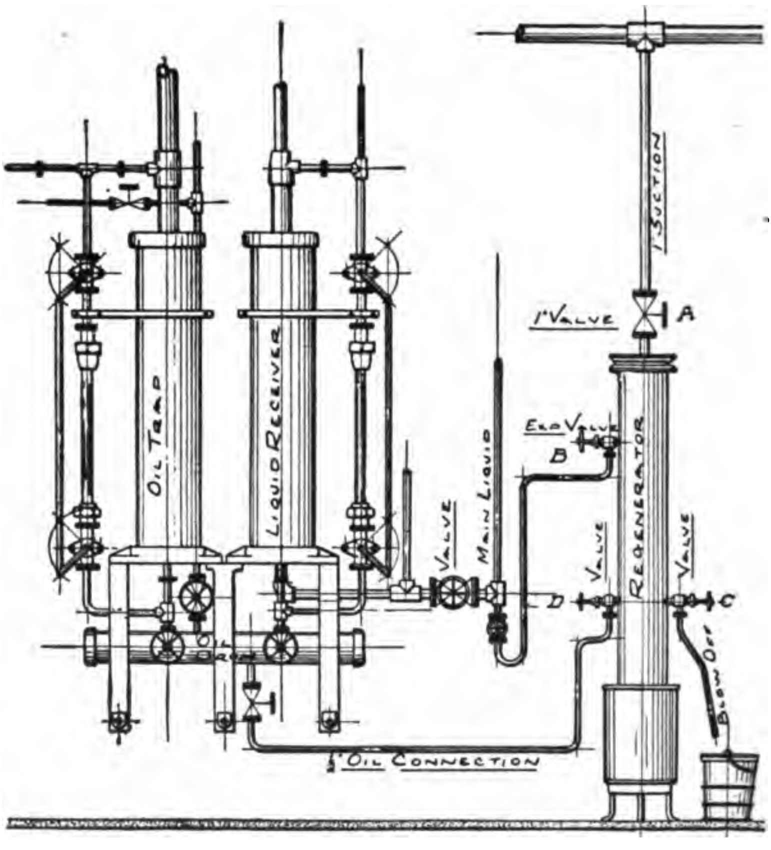
When no more liquid can be taken out of the system it contains nothing but air and gases resulting from the decomposition of ammonia and otherwise. These have no value other than to be used for testing and blowing out. It is preferable to use this devitalized gas for blowing out rather than to pump air into the system, for the reason that the air in passing through the compressor is heated and will vaporize the oil on the inner surfaces of the pipes. The carbon of the oil mixed with the oxygen of the air forms an explosive mixture that may be the cause of a serious accident.

How should care be exercised in re-filling drums or cylinders ?

A certain amount of gas space must be left in the drum so that there will be no danger of bursting it by expansion of the liquid ammonia, with change of temperature during shipment. The manufacturers determine what the gas space should be and charge the drums accordingly, so that it will generally be safe to fill the drum with the same weight of liquid that it contained when received from the factory. This amount appears on the books of the company in connection with the number of the drum so that there should be no mistake in the charging.

Is it advisable to draw the charge at the time a plant shuts down ?

As a preliminary to shutting down the ice plant, it is advisable to freeze the tank down solid and, generally speaking, it is advisable to draw off the ammonia charge as soon after shutting down as possible. By doing this, less of the charge will be lost by leakage through the joints, whose tightness is most probably affected by the contraction of the parts of the system that have been under strain at varying temperatures during the previous season. When the charge has been withdrawn, any part of the system can be examined without the necessity of raising steam to pump out.



This regenerator is connected up to the receiver of a plant. The liquid enters the regenerator through the pipe D and expansion valve B, and the pure vapor is allowed to escape by means of the valve A into the suction of the compressor. When charging the regenerator the valve A is closed, and during the distilling process the valve B is closed. C is a blow off.

In case the charge is withdrawn is it desirable to have it distilled ?

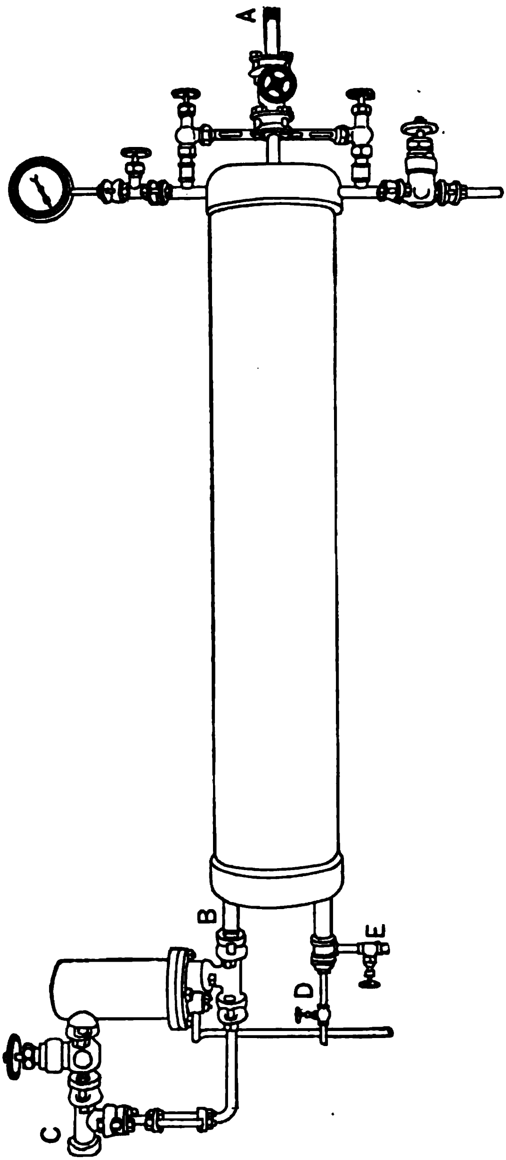
If there is no distilling apparatus installed in the plant, it will be necessary to ship the charge to the factory for re-working. In this way, the oil and water are removed and the gas is made like new. Every one who has operated a plant knows what an effect the charging of a new drum of ammonia into the system has on the operation of the plant. The cost of shipping and re-working the whole charge is not prohibitive by any means, but there will be a great saving effected in any plant by the installation of a distilling apparatus. The saving is not only the cost of the annual or periodical rejuvenating of the charge, but greater economy of operation may be had owing to the fact that the charge or a part of it can be distilled during the season's run as often as may be required to keep the ammonia at its freshest. With such a live charge of gas and constant attention on the part of the engineer to purge valves, the conditions are right for maximum economy.

Should all the parts of the system be properly proportioned ?

It is false economy to put in a badly balanced plant. Each part of it should be able to do its work with a reasonable factor of safety.

Why is it a mistake to use a machine of larger capacity than needed ?

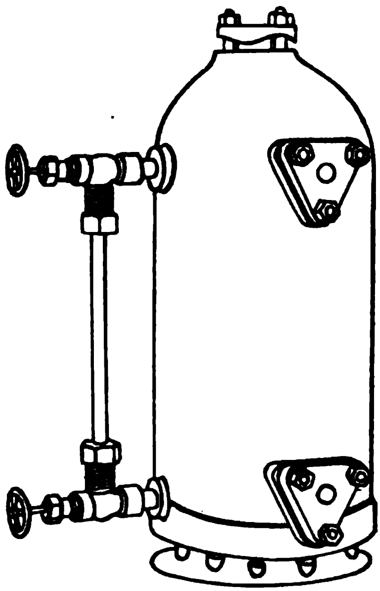
If you want a plant to produce 50 tons of ice per day, it is not economy to put in a 75 ton compressor, for it will have to be operated at a considerable loss to be run at 50 tons capacity. The investment is the same as if you were making 75 tons of ice and so is the wear and tear and the amount to be charged off each year for depreciation, hence unless it is the intention to increase the plant to the full capacity of the compressor within a year or two, it is a better investment to put in a compressor that will be operated up to its normal capacity.



Another type of regenerator. The ammonia enters through the pipe at the right and is evaporated by steam which enters through the small pipe to the left near the bottom this pipe is surrounded by a larger pipe through which the steam returns. If the pressure of the gas should rise above a certain limit it will relieve itself through a safety valve which is connected to the suction pipe of the compressor. The suction pipe with trap is shown at the left near the top.

What is a good composition for ammonia joints ?

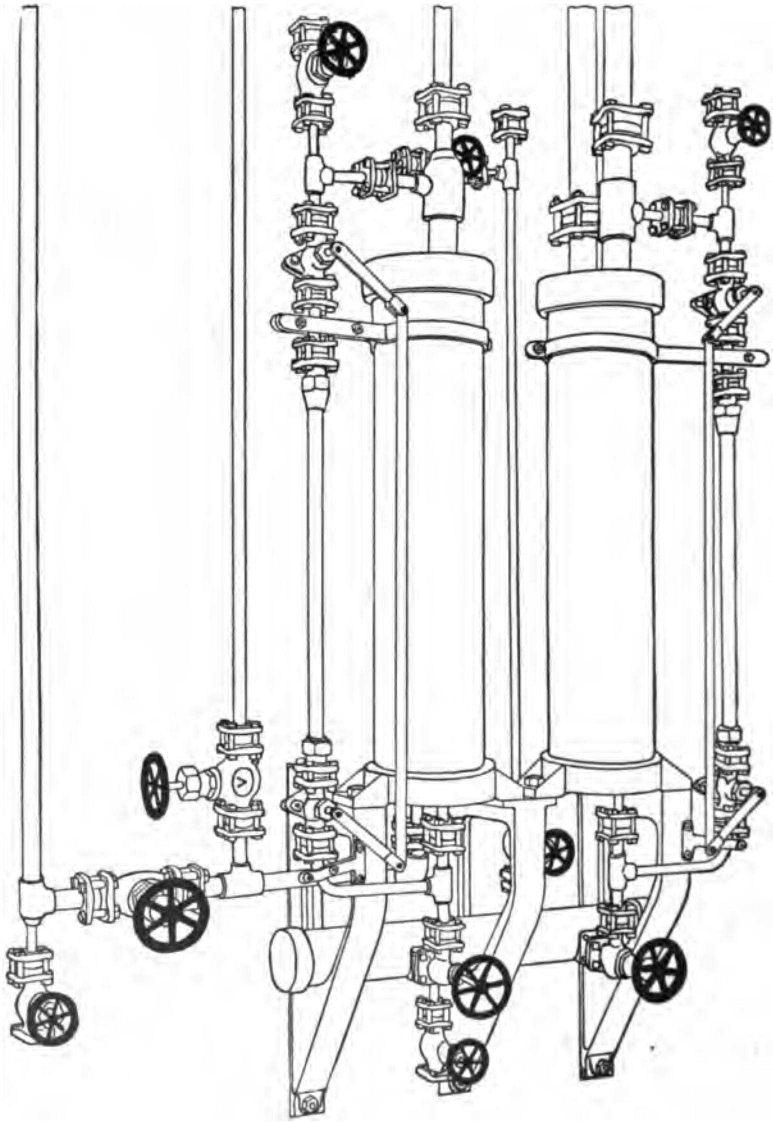
Mix a small quantity of litharge with sufficient glycerine to make a thick paint or thin putty. Put this with a brush on the thread of the pipe and screw the pipe into the fitting just like a well made steam joint. Then smooth the remaining mixture on the outside of the pipe and let it set. Setting must take place within from ten to thirty minutes or the litharge is poor or has



Ammonia receiver for small plants.

been mixed too thin. Be sure that not a trace of oil is either on the pipe or the thread of the fitting or the mixture will not harden.

All threads should be carefully cleaned with gasoline before using the litharge and glycerine, and the mixture must be made up only in such quantity as is needed at the time as it cannot be used after it starts to set.

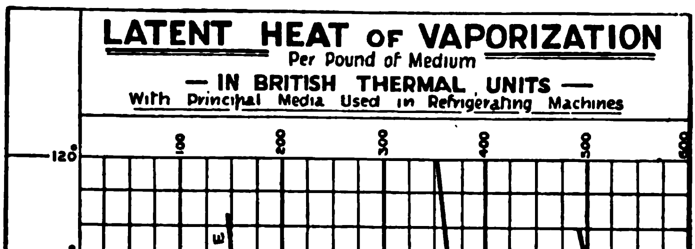


Oil trap and ammonia receiver mounted together on cast iron wall brackets.

What are the heat values and boiling points of the various liquids used in refrigeration ?

TABLE OF HEAT VALUES AND BOILING POINT.

SUBSTANCE	Boiling Point Degrees F.	Latent Heat B. T. U.	Specific Heat
Water	212.0	966.0	1.00
Sulphur Dioxide	14.0	168.7	0.41
Ether	—10.0	——	——
Anhydrous Ammonia	—28.5	573.0	1.0058
Carbon Dioxide	—140.0	141.0	0.955



In the above curves the effect of temperature upon the latent heat of vaporization is shown for the three principal substances used in refrigeration.
See tables on pages 624, 633, 637.

How is the capacity of a compressor often estimated, and why is it misleading?

The "rule of thumb" way of calculating the capacity of a compressor is to assume that a certain number of cubic inches of displacement per minute is equivalent to a ton of duty per twenty-four hours. For ice-making from 12,000 to 14,000 cubic inches displacement per ton is assumed, and for refrigerating from 7,000 to 8,000 cubic inches.

Therefore, the buyer is very apt to receive a wrong impression as to the capacity of the machine he is buying, because he is not always told that machines are rated on a certain temperature of condensing water, usually 60 degrees F. or less, and for every ten degrees increase of temperature of condensing water above the temperature at which it is rated the compressor has about 5 per cent. less capacity, that is, it must run 5 per cent. faster in order to have the necessary displacement. If the ice machine builder has rated the compressor at 65 revolutions per minute with 60-degree water and the buyer furnishes 80-degree water, the compressor must be run 12½ per cent. faster, or say 73 revolutions per minute in order to get guaranteed results.

What is the result of some experiments carried on along these lines by the York company?

An exhaustive series of tests with reference to cubic inches displacement per ton at different pressures with both the single-acting and double-acting machines has been undertaken, the single-acting machine used being the York standard vertical type and the double-acting, the Linde horizontal type. The size of the compressor in both cases was 12½-inch diameter and 18-inch stroke, or nominally 40 tons refrigerating capacity. The work done was measured by the pounds of brine cooled. The suction pressure and condensing pressure and work were maintained constant. All instruments used were carefully calibrated in order to get accurate results. The figures given are

the average of a series of five or six hours' duration each, indicator diagrams and readings of temperature being taken every fifteen minutes during the test. Tests were made at different back pressures running from five pounds to twenty-five pounds suction pressure. The comparison is shown by one series of tests at fifteen pounds' back pressure, as such pressure somewhere nearly approximates the average can ice factory back pressure.

TABLE.

CUBIC INCHES DISPLACEMENT PER TON OF REFRIGERATING DUTY.

	Single-Acting.	Double-Acting.
145-lb. condensing pressure.....	7829	8901
165-lb. condensing pressure.....	8092	9224
185-lb. condensing pressure.....	8362	9555
205-lb. condensing pressure.....	8630	9890

The ice-making capacity of a compressor being practically 60 per cent. of its refrigerating capacity, we have based on the above the following :

TABLE.

CUBIC INCHES DISPLACEMENT PER TON OF ICE MAKING DUTY.

	Single-Acting.	Double-Acting.
145-lb. condensing pressure.....	13050	14835
165-lb. condensing pressure.....	13480	15370
185-lb. condensing pressure.....	13940	15925
205-lb. condensing pressure.....	14380	16480

The horse-power per ton of refrigerating capacity at the different condensing pressures and at fifteen pounds back pressure is as follows :

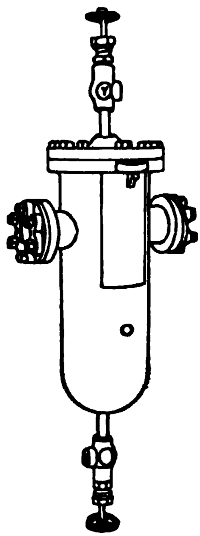
TABLE.

	Single-Acting.	Double-Acting.
145-lb. condensing pressure	1.195	1.358
165-lb. condensing pressure	1.341	1.529
185-lb. condensing pressure	1.486	1.700
205-lb. condensing pressure	1.631	1.870

What do these figures show ?

It will be noted that the horse-power per ton of refrigerating capacity at 205 pounds pressure is approximately 40 per cent. greater than it is at 145 pounds condensing pressure. This means that with conditions that compel operating with condensing pressure of 205 pounds the fuel bill will be practically 40 per cent. greater than with a condensing pressure of 145 pounds.

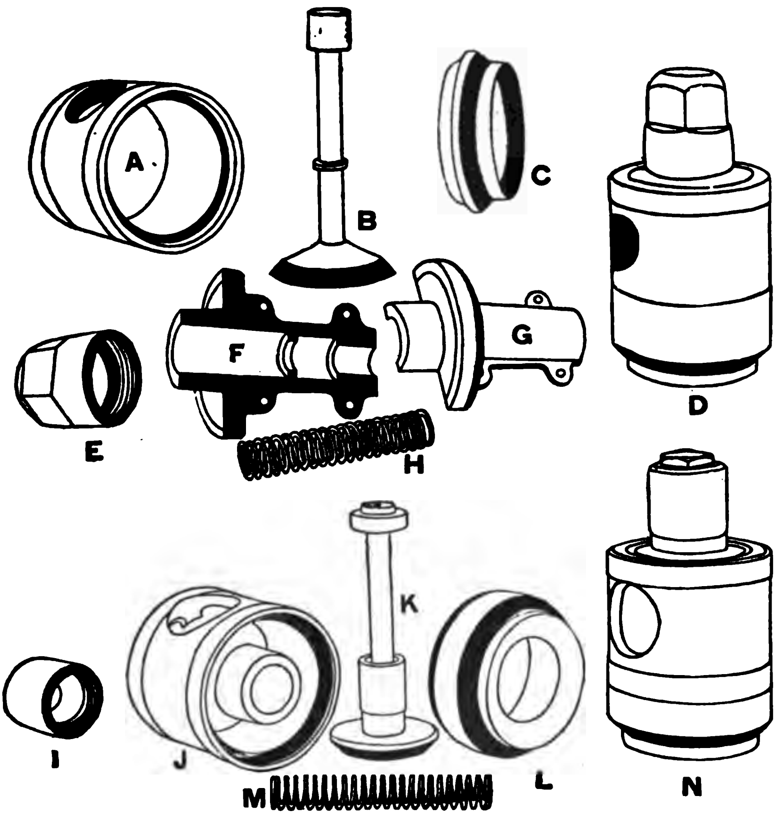
The figures also show that in order to get the compressor capacity at 205 pounds condensing pressure it must run about 12½ per cent. faster than at 145 pounds condensing pressure.



York ammonia strainer for removal of scale, oil or foreign matter.

What is the dryer ?

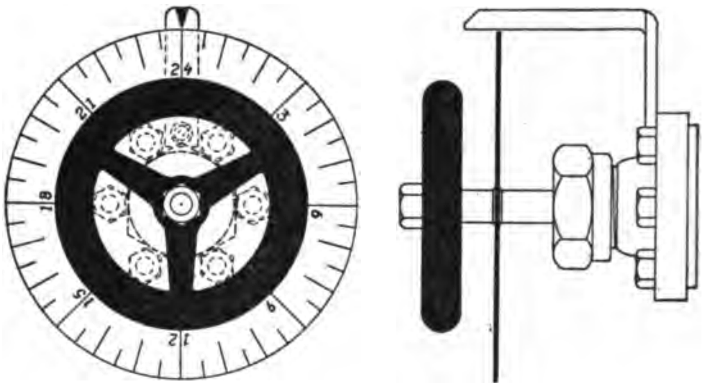
An apparatus placed on the suction pipe for the purpose of drying the ammonia gas, which, by means of a by-pass, can be run through it when necessary. It is a sort of trap provided with removable heads for the introduction of some such absorbent of moisture as freshly burnt lime.



Details of the Vilter compressor valves, showing the construction employed on horizontal compressors. A shows the suction valve cage; B suction valve and valve stem; C shows suction valve seat; the outside bevel face forms a gas tight joint in the valve chamber of the head. D exhibits the complete suction valve assembled; E the cushion cap. F and G valve guides are made in halves, on account of the collars on valve stem. H is the suction valve spring. The spring is placed on the valve stem under the collar by slightly opening the coils and winding it on the stem. I shows the discharge valve cap, and J the discharge valve cage. K is the discharge valve and stem; L discharge valve seat; M the discharge valve spring, and N the complete discharge valve assembled.

Describe a method for marking the operating position of valves ?

In a refrigerating plant with its numerous valves requiring at times the most exact adjustment some scheme of marking becomes absolutely necessary, and can be accomplished by a system of dials with pointers which will intelligently indicate valve positions without disfiguring the valves.



Dial and indicator attached to valve handle. The marking of the dial can best be done by fastening the disk to a wooden block attached to the faceplate of a lathe, and moving the carriage with a pointed tool across the disk so as to take a light cut.

The spacing can be done by placing a suitable gear on the spindle and moving the faceplate after each cut until the next tooth comes in line.

Provide a disk of sheet brass, say, 1/16 inch thick and 6 inches in diameter, for a 1-inch valve; divide the outside edge into a suitable number of divisions depending on the fineness of adjustment desired, and stamp each division with a figure punch or if graduated close, at intervals, so that the figures will not become confusing. Attach the dial to a small brass collar which is secured to the valve stem by a small set-screw. Set the dial on the valve stem so that the pointer will be at zero when the valve is closed. If the valve is opened more than one turn, it will be necessary to count them and read the fraction of a turn directly from the dial.

This device has proved of great advantage in operating a refrigerating plant. It has been placed on the expansion and weak liquor valves, also the steam valves to the retort pump and the condensing water valves.

How should a mercury well be placed?

The socket should be at least three inches long, and if the pipe is not of sufficient diameter larger-sized tees, with outlets bushed should be provided to receive them, or a mercury well may be attached to the outside of a small pipe, as shown in the figure on page 102. This method is particularly adapted for pipes that are already erected, and there will be no obstruction in the pipe. The iron around the socket should be thin so as to transmit the heat readily.

When will ammonia become a solid?

At -115 degrees Fahr.

How does aqua ammonia come from the manufactory?

Sixteen degrees aqua, containing about 10 per cent., called F. F. F.

Eighteen degrees aqua containing about 14 per cent., called F. F. F. F.

26 degrees aqua, containing about 29¼ per cent., called "stronger aqua."

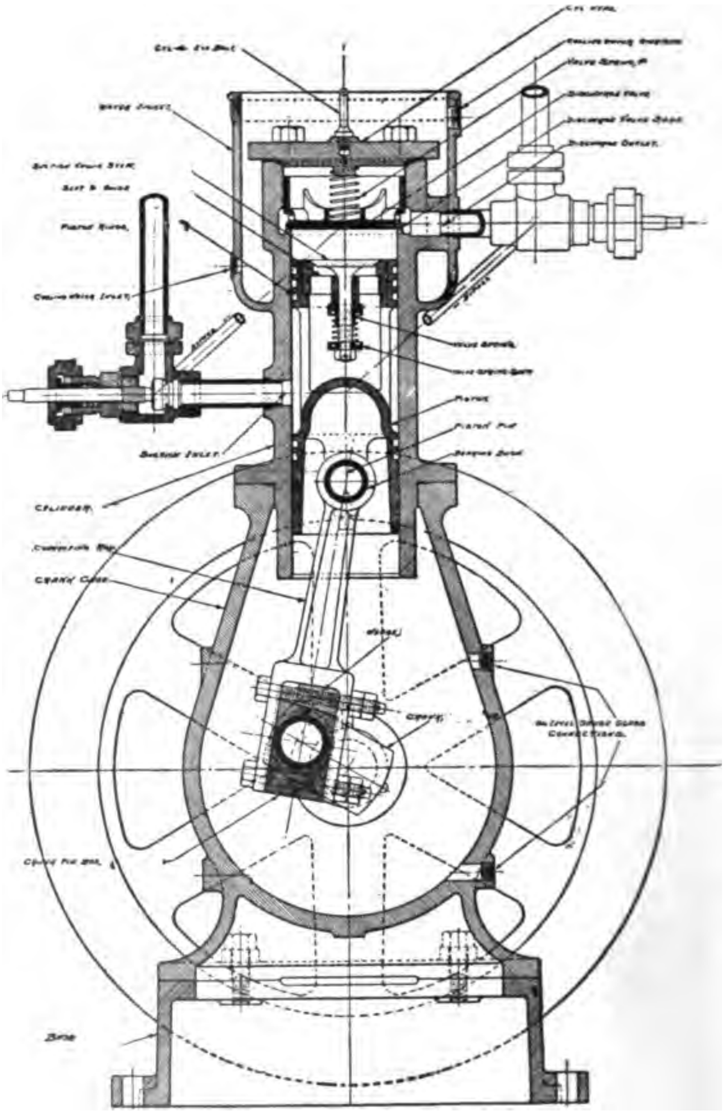
What is the amount of anhydrous ammonia in 26 degrees Beaumé aqua?

38½ per cent. by volume. (See page 369.)

What do we mean by strong and weak liquor?

The terms are entirely relative; the former has a density of from 25 to 30 degrees by the Beaumé scale and the latter from 14 to 16 degrees. At various times the ammonia liquor in a plant may have any density ranging between these figures.

In both cases it is simply a solution of ammonia gas in water.



The Miniature Triumph Compressor.

THE AMMONIA CONDENSER.

Where does the ammonia go after leaving the compressor ?

To the condenser, where it is liquefied.

What is the primary use of the condenser ?

The office of the condenser is to liquefy the ammonia gas as it is discharged from the compressors, and the work done in the condenser is the taking up of the latent heat of vaporization plus part of the heat generated by compression.

What are the different models of condensers ?

The (1) atmospheric, (2) the double pipe, and (3) the submerged.

Which form is most desirable ?

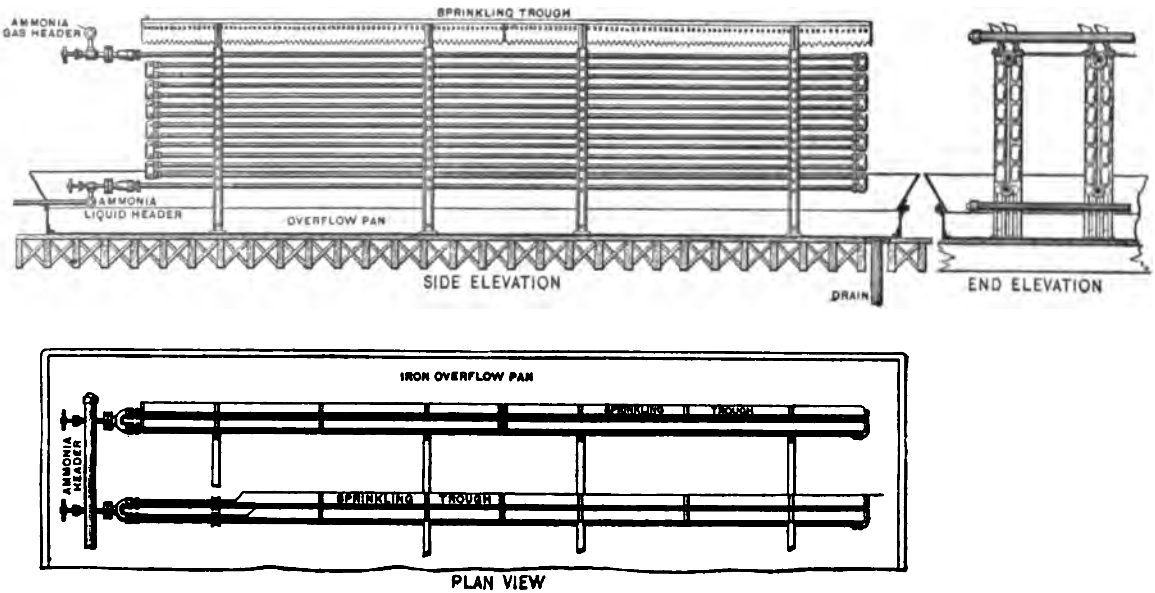
That depends upon the proposed location and size. If it can be placed on the roof or in an open room, the open air condenser is preferred on account of its more economical use of water, and it is easy of access in case of repairs.

What other form is very efficient ?

The double pipe condenser is favored where water is to be used over again for some other purpose and where the open air style cannot be used on account of building construction. This style is made with one pipe inside of another. The water being on the inside of the inner pipe and the ammonia in the annular space between the pipes.

Where is the submerged type best used ?

The round coil submerged condenser is used with small machines, or where the condenser must be placed in a closed room.



ATMOSPHERIC AMMONIA CONDENSER WITH IRON OVERFLOW PAN. The water, after passing over the coils accumulates in the pan, and is taken up by a pump and again discharged into the sprinkling troughs. In ice plants the water is frequently carried to the steam condensers, and after being cooled in a cooling tower it is used again on the ammonia condensers.

Why is a good supply of water so important ?

Be sure of a supply of water for condensing purposes before spending a dollar for any other purpose, for water is as necessary as coal, if not more so, and there are refrigerating plants where the daily use of water is not less than 500,000 gallons.

What is the main thing to be considered in the selection of a condenser ?

The arrangement of the condenser which secures the minimum temperatures within the coils through the use of the least amount of condensing water, is the most efficient, preference being given to the simplest form.

Describe the atmospheric type of condenser.

This type of condenser consists of coils of pipe through which the ammonia is forced, cold water being allowed to flow over the outer surface of the pipes.

Atmospheric condensers are doubtless the most common type used, and have been found highly efficient. The water is sprayed on top of the coils, and flows downward over each succeeding coil into the drain below the condenser, whence it is conducted to the sewer or the cooling tower, in the latter case to be used over and over again.

How is the cooling water controlled ?

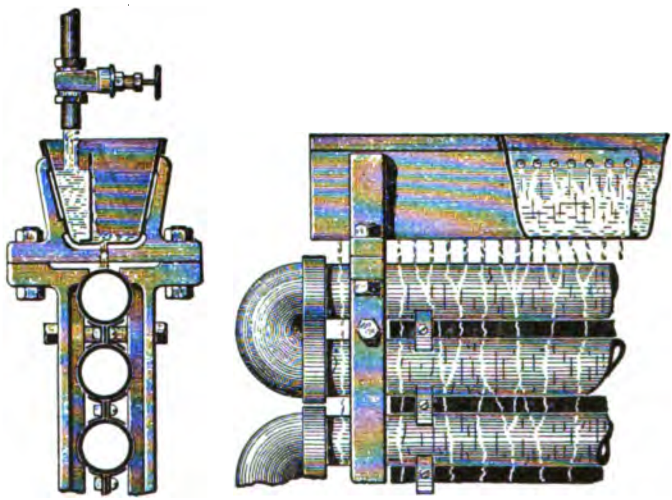
The water is distributed over the condenser from a slotted gutter-pipe which is fed from a water-box in the center ; each end of the gutter-pipe should be provided with a simple and reliable leveling device. Spattering is prevented by fins or strips of metal attached to the under side of the pipes which lead and guide the water in its descent from one pipe to the next.

To what fact is the efficiency of this type due ?

The great efficiency of this type of condenser is due to the rather high velocity of the water passing over the pipes, and to the cooling effect of the air on the water.

What is an important advantage of its construction ?

It will be seen that a construction which admits of the ready removal of any individual pipe without disturbing the other connections is an advantage should it become necessary to replace a pipe.



Condenser coils with trough and strips between pipes to prevent spattering of the circulating water.

How do atmospheric condensers differ in arrangement ?

There are two general styles of atmospheric condenser, that in which the hot gas enters at the top and flows downward, and that in which the hot gas enters at the bottom and flows upward. The noticeable defect in the former is that the coldest water comes in contact with pipes containing the hottest gas, and, therefore, having the highest temperature.

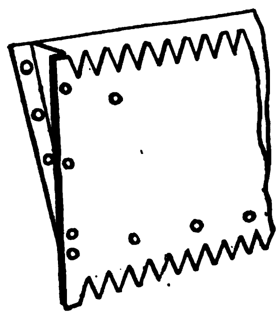
How is this difficulty met?

In order to overcome this difficulty and to obtain the advantages of the counter current principle, atmospheric condensers have been constructed for receiving the hot gas at the bottom, and suitable provision has been made for drawing the liquid ammonia from the coils as fast as it is formed, as shown in the figure on page 94.

What is the usual method of taking off the ammonia?

The usual method of withdrawing the liquid ammonia is to connect the ends of several of the pipes in the condenser with a header leading to the ammonia receiver.

If the liquid ammonia is not removed it will back up toward the compressor or generator, and trouble and damage may result.



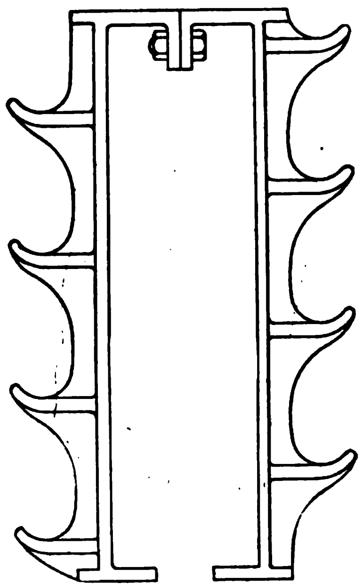
Atmospheric condenser trough. The saw tooth edge of the metal distributes the water evenly along the pipe and prevents spattering.

How high should an atmospheric condenser be made?

Take a thermometer and note the temperature of the cooling water on and off an ammonia condenser. If so, you will observe that the temperature gradually rises until about the sixteenth pipe is reached when the cooling water has performed about all the duty that is within its power. It is obvious, therefore, that it is useless to build such a condenser more than sixteen pipes in height.

Is the proper working of the condenser very important ?

The economy with which any plant may be operated depends to a large extent upon the condenser, and no harm is done by having it a little larger than is absolutely necessary. Care must be taken to have the water flowing over a condenser so distributed that all the radiating surface possible will be covered, because a much higher efficiency is thus obtained.



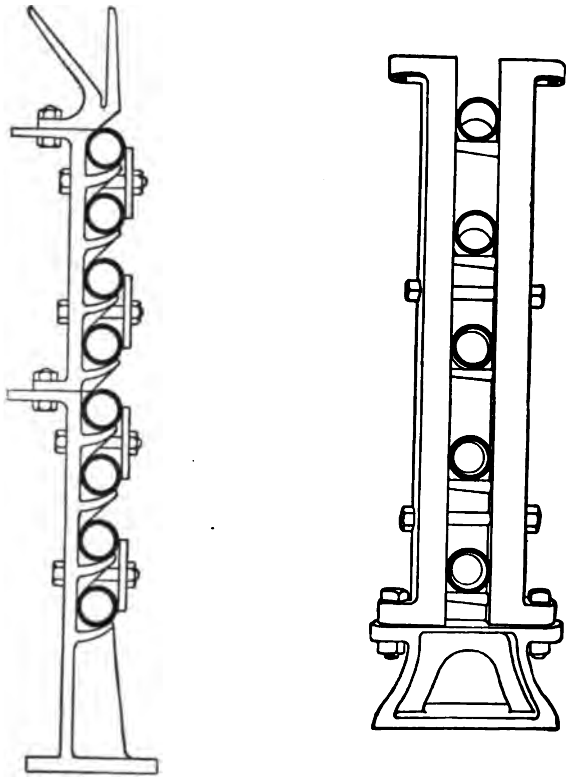
Cast iron stand for expansion coils.
(Trombone type)

How about the care of condensers ?

A careful watch for leaks should be maintained, the water should flow evenly, covering the pipes equally, and in the use of double-pipe or shell condensers it is well to thoroughly flush the water pipes occasionally to remove any coating or obstruction that may form in them.

Is cold condensing water very desirable ?

Get the coldest and best water available, and use as much of it as you can economically. Water always costs something, if it is only the cost of pumping.

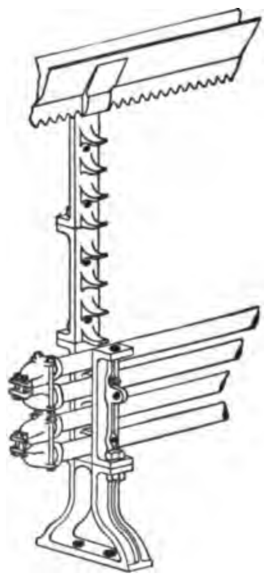


Cast iron stands for atmospheric condensers.

If the water has to be bought, balance the expense of the water against the cost of the fuel, and run the plant on an all-round economical basis ; remembering, the lower the condenser pressure the less the load will be on the engine, and the less fuel will be required to drive it.

Does the water supply need special regulation?

Up to a certain point, the velocity of the condensing water may be increased more economically than new condenser surface can be added. This will vary in different plants, since it depends upon the cost of water, the arrangements for using the condenser discharge, and the expense of pumping the additional amount of water. Each engineer must determine for himself when an increase in the condensing water will be more economical than obtaining a new stand of condenser coils.



Atmospheric condenser pipe stand with dripping trough.

What is the general rule as regards condenser area?

Common practice among the trade has established a rule, viz., to allow 24 square feet of condensing surface per ton of refrigerating capacity, when operating with a cooling water temperature of from 58° to 70° Fahr., which is equivalent to approximately 38 lineal feet 2-inch pipe per ton of duty.

How is it dependent on local conditions?

As the temperature of water is never the same in any two plants the amount of piping in the atmospheric condenser must be proportioned to suit the local conditions. The following table applies to atmospheric condensers, giving feet per ton capacity.

TABLE.

For water at Deg. F.	1 inch pipe.	1¼ inch pipe.	1½ inch pipe.	2 inch pipe.
50	60 feet	50 feet	40 feet	31 feet
55	65 feet	55 feet	45 feet	33 feet
60	75 feet	60 feet	50 feet	36 feet
65	80 feet	65 feet	55 feet	40 feet
70	85 feet	70 feet	60 feet	43 feet
75	92 feet	76 feet	67 feet	46 feet
80	98 feet	82 feet	73 feet	50 feet

What amount of water is required for an atmospheric condenser?

The amount of water required per minute per ton of refrigeration for atmospheric condensers is

TABLE.

At 50 degrees F. allow ½ gallon per minute
At 55 degrees F. allow ⅝ gallon per minute
At 60 degrees F. allow ¾ gallon per minute
At 65 degrees F. allow ⅞ gallon per minute
At 70 degrees F. allow 1 gallon per minute
At 75 degrees F. allow 1¼ gallon per minute
At 80 degrees F. allow 1½ gallon per minute

These quantities are based on water leaving the condenser at 95 degrees F.

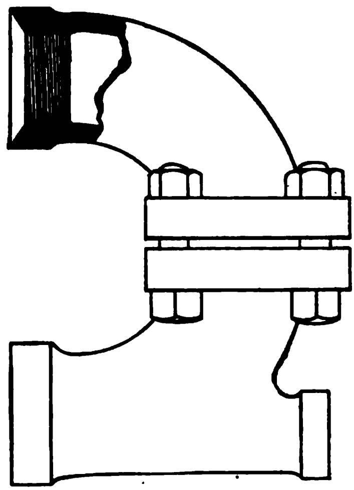
To find the amount of water required per day multiply the amount given for the temperature of the water by minutes in a day of 24 hours and by the number of tons refrigeration required.

How is the air used as an auxiliary in the atmospheric condenser ?

When there is a good breeze the air may carry off a considerable portion of the heat taken up by the cooling water.

How does the ammonia gas usually enter the atmospheric condenser ?

It enters the bottom of the condenser, and as it rises it cools and liquefies ; it then passes off into a vertical manifold and goes to the liquid receiver.



Divided and return bend with outlet for ammonia collecting pipe.

Do ammonia compression and absorption machines use the same condensers ?

There is little or no difference.

What is theoretically expected of the cooling water ?

That it will carry away the heat taken up by the ammonia while passing through the refrigerating coils, also the heat equivalent to the work done upon the ammonia by the compressor.

How should the gas and water be introduced ?

In all cases the relative flow should be contrary, that is, counter-current. In the submerged type the gas should go in at the top and the water at the bottom ; in the atmospheric type the gas goes in at the bottom and the water flows in at the top.

Where is the atmospheric condenser usually placed ?

It is usually put on the roof, if possible, so as to be in a constant draft of air. Water is allowed to trickle or drip over these pipes from a trough placed above them all ; it usually flows through perforations in the trough or serrated edges in its side.

Why are condenser troughs made with serrated edges ?

The object of the serrated edges is the more even distribution of the water, owing to the fact that while it would be practically impossible to obtain a uniform flow of water over a straight and even edge of a trough, particularly if the amount is limited, it is an easy matter to regulate the flow through the V-shaped openings.

Could condensers be used without water ?

It is possible to use a dry atmospheric condenser, but it would require five times the surface area of an atmospheric condenser of the usual type.

What are some special types of atmospheric condensers ?

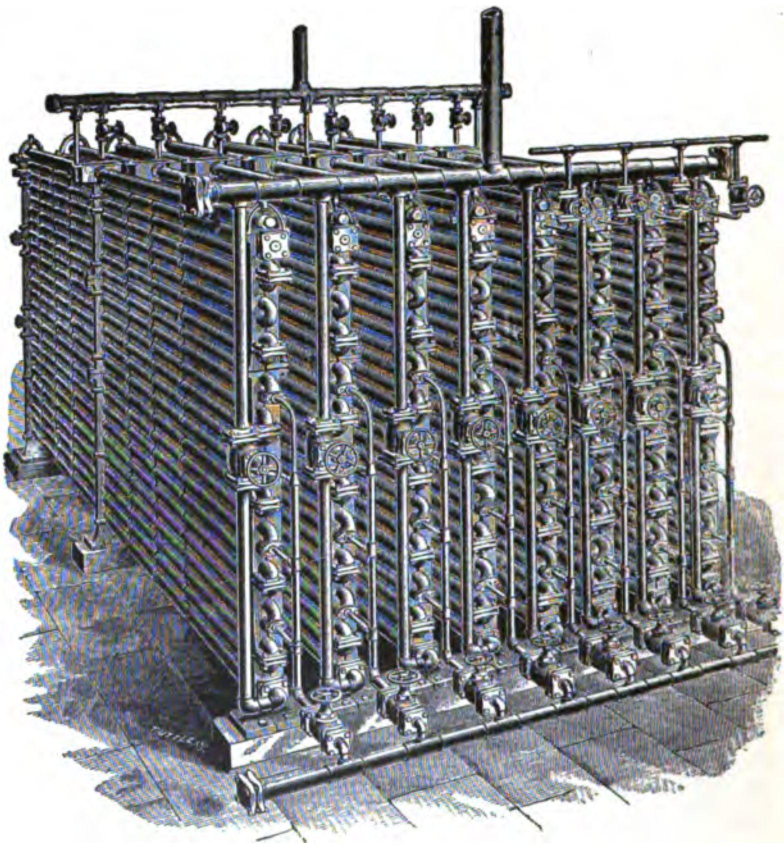
Several special styles of atmospheric condensers, known as two and three-story condensers, have been designed, but they have found but little favor in this country. Such a condenser is divided into two or three sections, and the hot gas is conducted into the top of the lower sections, and flowing to the bottom, thence to the top of the next higher section, and so on until the gas entering the top of the coil has been appreciably cooled.

What can you say of the material used in condenser construction ?

It must be of extra heavy pipe and of the very best quality.

How does the De La Vergne condenser differ from the general type of condenser?

It has a series of return bends so that the liquefied gas can be drawn off at different levels, the gas entering the condenser at the bottom instead of the top. See figure on page 150.



De La Vergne atmospheric condenser, showing the collecting pipes at various levels. In order to obtain the counter current effect the gas has to enter at the bottom of the coils, as the water is running over the coils from the top. It is necessary in such condensers to draw off the liquid at various levels to prevent choking the coils. See also pages 94, 150 and 206.

Why is it mistaken economy to have too small condenser capacity ?

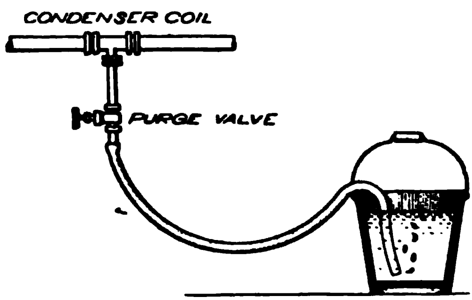
In order to understand what it costs to economize in the installation of condensers it is necessary to consider its relation to the economical operation of the plant. Let us assume that with a condenser of ample size we are able to do the required work with, say, 150 pounds head, and 15 pounds back pressure. In this case the difference between the two pressures will be 135 pounds. If, on account of high condenser temperature we are compelled to operate with 180 pounds head pressure, the back pressure remaining the same, the compressor will have to do about 33 per cent more work to accomplish the same amount of refrigeration, as with the lower condenser pressure.

If we have the plant designed with a view to obtaining the maximum economy with a normal load, that is, with say, 15 pounds back pressure and 150 pounds head pressure, then as the load on the compressor increases the load on the engine will increase also, and hence the economy of the engine will decrease owing to the later cut-off and less expansion, so that instead of the steam consumption merely keeping pace with the increase of work on the compressor it will exceed it, and instead of representing a loss of efficiency of 33 per cent. it will exceed this amount.

If we consider a plant burning ten tons of coal per day with normal conditions as stated, and should operate it under the less favorable conditions as mentioned, we would increase the fuel consumption about 40 per cent. Hence, if we are burning a cheap grade of coal, costing, say, $2.50 per ton, the increase will represent, say, four tons per day, and this, at the price stated, would amount to $10.00 per day, $70.00 per week, or $300.00 per month of thirty days. This would pay a considerable bill of pipe and fittings. Yet, there are many plants with condensers of insufficient capacity.

How should the condenser be looked after ?

Observe the glass gauge on the condenser. There should be two or three inches of liquid in the glass. This should be alive, full of bubbles, chasing up and down. If the machine has been running for a time and this liquid is still and dead, there is air or foul gas in the rectifier or condenser or somewhere in the system. Should there be no liquid in the gauge and it is not possible to get it there with the steam all on, it needs strengthening with more anhydrous.



Method of removing air and gases from condenser.

How can the engineer tell when he needs to increase his charge of ammonia ?

By carefully watching his condenser pressure ; a reduction of 10 or 15 pounds, while the suction and condenser exit pressure remained the same, would show the necessity for making up a leakage loss.

How may the condenser water be used again ?

It should be used as boiler-feed water.

What should be the pressure in the condenser ?

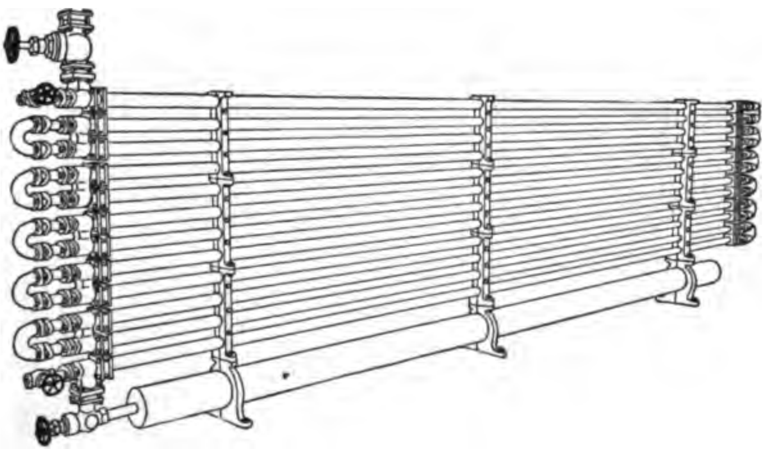
It depends on the temperature of the condensing water, the tension of the ammonia vapor being about ten pounds higher than the temperature of the water leaving the condenser.

What two pressures and temperatures show economical working ?

The lower the pressure and temperature in the condenser coils and the higher the temperature and pressure in the expanding coils (the back pressure) the more efficient is the working of the machine.

What is very important in producing the first condition ?

Condenser water as cold and in as great profusion as possible.



Double pipe ammonia condenser with receiver attached. The drum at the bottom of the coils forms the receiver space; this arrangement simplifies the piping considerably.

How is a condenser sometimes also made to do duty as a liquid receiver ?

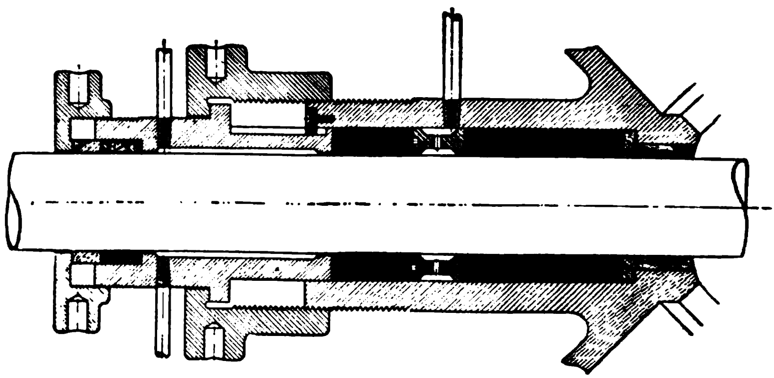
Although it is not generally considered the best practice, the lower pipes are sometimes used to store the liquid ammonia, thus eliminating the ammonia receiver from the system, the ammonia being drawn directly from the condenser coils and passed through the expansion valves.

What is the oil trap?

An arrangement placed between the compressor and condenser to intercept the oil which may be drawn over with the ammonia from the lubricating material used in the stuffing box.

Is more than one used?

Frequently two may be considered advisable, the larger one near the machine, and the other just before the condenser.



The Vilter stuffing box differs somewhat from the Linde type. The main gland forms an oil chamber.

What is the forecooler?

A coil or series of coils through which the ammonia gas passes before it enters the condenser proper. It is cooled by the overflow water from the condenser, and is intended to supplement, or rather reduce, the work of the condenser.

It is an adjunct to the condenser which may be of importance in some cases, like the economizer of a steam plant, and of no great value in others. If a part of its duty is to separate oil from the gas it is, of course, an indispensable part of the system.

Why should special care be taken to prevent oil from entering the condenser coils?

Oil is a poor conductor of heat, and special care should be exercised to have the ammonia free from it before the ammonia enters the condenser coils. As little oil as possible should be allowed in any of the piping through which heat is to pass. This feature is neglected in too many plants and inferior trapping apparatus used. In overhauling a plant it is a good plan to disconnect all piping and blow steam through it to loosen any oil that may have adhered to it. Afterward force a stream of water through and follow this with air in order to drive out all the water and dry the pipes for the ammonia.

When two liquids or gases are to transfer heat how is the flow spoken of?

As parallel currents, and opposite or counter currents.

How do they come together?

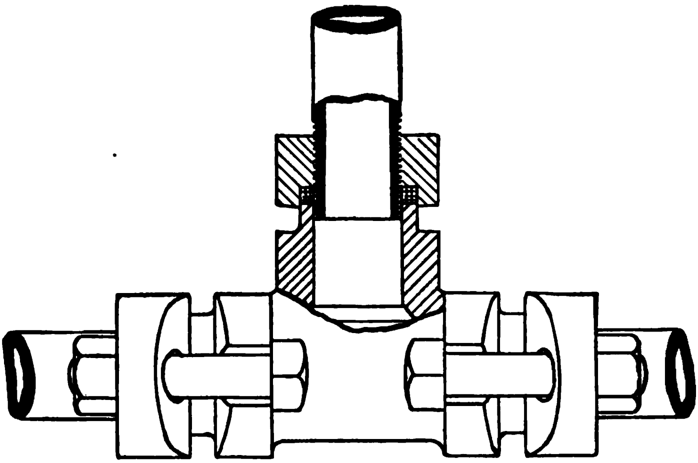
In the parallel current flow the one to be cooled should be at its warmest and the other at its coolest when they meet; in the latter both have their highest temperature at one end and their lowest at the other.

How does the temperature of the cooling water affect the working of the compressor?

The temperature of the cooling water determines at what pressure the ammonia gas shall be compressed in order that it may be liquefied in the condenser. For example: When the temperature of the cooling water is about 70 degrees the condenser pressure in the ammonia system should not be less than 150 lb. gauge pressure, and with higher temperatures for the cooling water the pressure must be increased correspondingly. At 60 degrees the pressure should not exceed 125 to 130 lbs., and with deep-well water of about 54 degrees, a condenser pressure of 105 to 110 lbs. will be found sufficient.

Explain how the temperature of the cooling water is very important in condenser operation.

The ice manufacturer who has condensing water at 80 degrees F. must not expect to get as much ice from a compressor of a given size and speed as the man who has condensing water at 60 degrees F. and the buyer who has 80-degree water for condensing purposes should certainly buy a larger compressor for a given amount of work than would be required by the man who has 60-degree water.



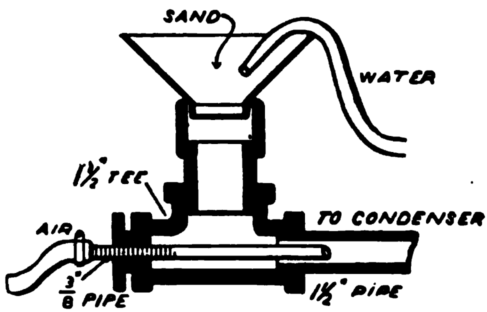
Flanged end ammonia tee. The pipes are screwed into the flanges, which are drawn up by bolts. The packing being compressed well into the thread makes an absolutely tight joint.

The effect of condensing water temperature on the capacity and horse-power of ice-making and refrigerating machines is very important, and perhaps is not taken into consideration as much as it should be by users and certainly not by buyers of this class of machinery. The buyer of a steam engine will be careful to specify the steam pressure, speed, etc., under which he intends to operate, but the buyer of an ice plant nine times out of ten does not know the conditions under which it will be operated.

He wants a plant of so many tons capacity, and if asked the temperature of the water to be used for condensing purposes is surprised that any time should be wasted on so unimportant a matter.

How should valves be arranged for cutting out a part of the condenser ?

In setting up a condenser for ammonia the branch pipes, from the discharge to the compressor, as well as from the liquid return pipe should have valves placed in them. In this case if a defect occurs in any stack of coils in the condenser it is an easy matter and takes but a little time to pump down and cut out the defective stack, and then go on with the operation of the plant while repairs are being made.



Ejector for cleaning out condenser pipes.

How would their absence complicate matters ?

If these valves are not provided the remedy would be to pump out the condenser, break the joints of the discharge inlet and the liquid return outlet from the defective stack, and place a blind flange on the pipes, which would be a great inconvenience and would also require more time than if the valves were placed as suggested. In a refrigerating plant, when all the capacity of the plant is required, anything that saves time saves money.

When the ammonia is liquefied in the condenser how should it be cared for ?

After the ammonia is liquefied in the condenser, care should be taken that it does not come in contact with heat greater than its own, and for this reason it should never be piped through the engine room or boiler room, unless the pipe is insulated.

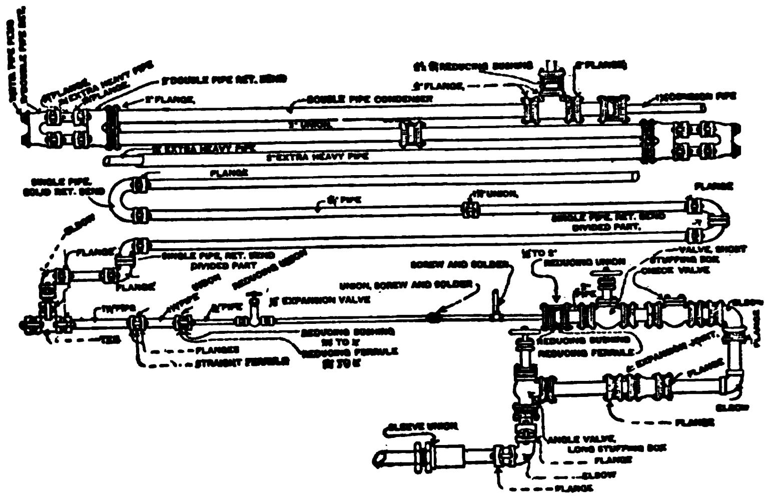


Diagram showing different connections made with ammonia fittings.

How will the condenser and refrigerator temperatures run ?

The temperature of the ammonia in the condenser will always be a few degrees higher than the water leaving the condenser, and the temperature of the ammonia in the refrigerating coil will be 5 to 10 degrees lower than the outgoing brine.

What is specially important in making pipe joints ?

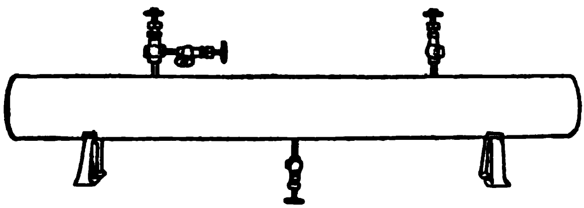
That the pipe screws into the fitting the proper distance and that the thread is well-fitting, otherwise there is sure to be a leaky joint sooner or later. It is particularly liable to make trouble if on the high pressure side.

How are permanent gases formed ?

The decomposition of ammonia may be due to unnecessary heating of the gas during compression, and the presence of air to the pumping of a vacuum which some engineers unwisely do whenever they stop the plant for any length of time.

Why are they objectionable ?

If the amount of permanent gas is small and there is liquid enough in the condenser coil to act as a seal, it does no great harm, it only requires a little more cooling water on the condenser. If these gases, however, are present in large quantity and especially if the liquid in the condenser runs low so that it no longer acts as a seal the permanent gases will go all over the system, interfering with the correct working of the gauges.



Horizontal ammonia receiver for small plants.

How is the presence of foul gas detected ?

Should there be evidence of foul gas, which is usually shown only by the machine not being up to duty or by the liquid in the condenser gauge being dead, the whole machine needs purging. From the condenser, the air and foul gas is drawn off at the top. Have a pail of water handy and put the end of the pipe into it, opening the valve slowly. Air or gas present will show as bubbles, as the air is not absorbed by the water. When the air and foul gases are gone the bubbles stop and there will be a crackling sound, something like that produced by turning steam into water, which is caused by the water absorbing the ammonia, and when this sound is heard the valve should be closed.

What would be a satisfactory way of disposing of the foreign gases of whatever nature ?

What would seem to be the rational method of getting rid of all the fixed gases, including not only the hydrogen, but also the air and nitrogen, would be to shut off one of the stands of ammonia at a time. This would probably not result in a prohibitively high head pressure if the machine were allowed to operate at full speed. If the head pressure did become abnormal, a reduction of speed would remedy the trouble. The water should be left running over the closed condenser stand until it is thought that the ammonia gas is well liquefied. The purge valve may then be opened and the gases allowed to escape, preferably through a small rubber hose, into a pail of water.

In drawing off gases how may the ammonia be recognized ?

All of the permanent gases can be easily recognized, as they will escape in the form of bubbles from the water in the pail. The presence of ammonia is also readily recognized since it goes into solution in the water with a crisp crackling noise and no bubbles will appear.

In purging a condenser of foul gases should the compressor be shut down ?

The compressor should be stopped and water be allowed to flow over the condenser until it is cooled down.

How are the condenser purging valves arranged ?

Every condenser coil should be provided with a purging valve, and if the condenser consists of a number of coils, all of the purging valves should be connected to one air header for blowing out the air or foul gases. Much ammonia is wasted by blowing the purging valves into the atmosphere until the bluish ammonia gas can be seen. This is absolutely wrong and should not be practiced, because much ammonia passes off before the bluish gas can be seen.

What is the object of the purge valves of the condenser and why are they essential?

The object of purge valves on an ammonia condenser is to enable the engineer to blow off the **permanent** gases that accumulate in the system.

What may these permanent gases be?

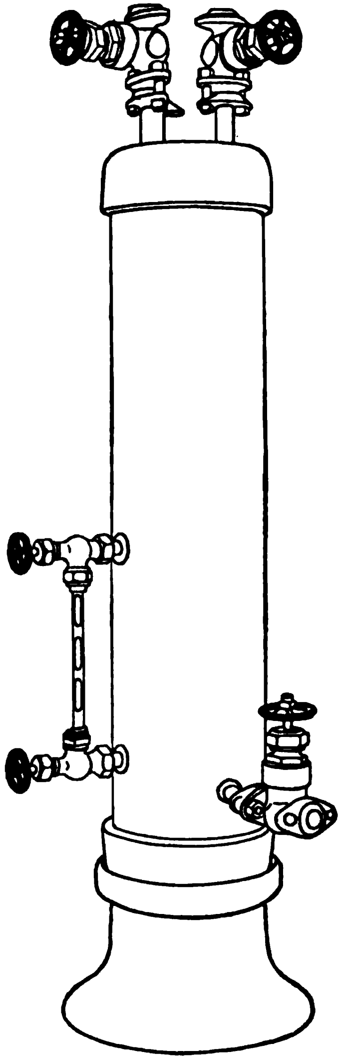
These gases may be of two different origins. They may be due to the decomposition of ammonia, in which case they constitute a mechanical mixture of hydrogen and nitrogen, or they may be little more than air which has got into the system accidentally when some part has been opened up for repairs, or through leaks around the ammonia rods when a vacuum has been pumped on the system.

What are they most likely to be?

As a matter of fact, the permanent gases most commonly encountered in ammonia refrigerating systems are the hydrogen and nitrogen resulting from the decomposition of the ammonia. The hydrogen constituent will rise to the top of the condenser because of its lightness compared to nitrogen or even to ammonia. As compared to air taken as unity, the specific gravity of hydrogen is 0.06926, that of nitrogen is 0.971, and that of ammonia 0.6.

Where in the condenser do they tend to go?

Other things being equal, the ammonia of an air and ammonia mixture will flow to the top and the air to the bottom of the containing vessel. Air does, nevertheless, collect in the condenser whether it be the highest point in the system or not. The reason for this is that it is carried along with the ammonia gas, and the gas, being liquefied in the condenser under the proper conditions of temperature and pressure, leaves the air behind.



Vertical ammonia receiver with gauge glass and pedestal.

Why is air objectionable ?

Air in the system excludes an equal volume of ammonia gas, and, therefore, reduces the available condensing surface. Special provision should be made for air venting the condenser.

Why is it impracticable to draw off air from the bottom of the condenser ?

It might tend to gravitate out of the condenser at the bottom, but it would be prevented from doing this by the presence of the liquid ammonia, which, although it is comparatively light for a liquid is still many times heavier than air. Furthermore, ammonia condensers are usually built so that the outlets are liquid-sealed, making the escape of a gas in that direction impossible.

How should the purging be done ?

The proper way is to provide the purging valves or header with a one-quarter inch pipe, which has a rubber hose stripped over the end. Stick the hose into a can or barrel filled with cold water, and note while blowing whether large air bubbles are leaving the hose and rising through the water. If this is the case, air is discharged, but when only small bubbles or occasionally a few large ones appear, more ammonia than air is blown out, and the purging should be stopped. After running cold water over the condensers for about one hour, another trial can be made, but this should always be done while the condenser coil to be blown is not in operation.

Can this water used in purging be made available ?

In a compression plant, all the ammonia blown out and absorbed by the water is wasted, unless it is used for washing and cleaning. But in an absorption plant the ammonia can be used by pumping the weak solution into the system, which will prove to be much the better way than to "burn off" the foul gases, as usually practiced.

How are air and various permanent gases removed from other parts of the system?

For the purpose of removing these undesirable gases, purge valves are provided in different parts of the system. One of these is commonly placed in the bottom of the oil separator for draining off the oil, which is brought over from the compressor. If a vertical ammonia receiver is used, a purge valve may be placed in the bottom, and the liquid ammonia be taken off from the side of the receiver 4 or 5 inches from the bottom. Other points of connection are the bottom of the brine cooler or lower manifold of the coil in the tank system.

Is there any waste of ammonia in a compression or absorption system?

Theoretically there should not be, but in actual practice from 50 to 100 pounds yearly is regarded as practically unavoidable in a plant of moderate capacity.

Why is this?

It is partly due to leakage and also to decomposition of the ammonia into hydrogen and nitrogen. The former may be largely caused by inefficient management, the latter is very difficult of prevention.

How should precautions be taken to prevent air from getting into the system?

To prevent the possibility of air getting into the system, the evaporating pressure should never be brought below that of the atmospheric, or 0° on the gauge, as at such times, with the least leakage at any point, it is sure to enter. Should it become necessary to reduce the pressure below that point, it is well first to tighten the compressor stuffing boxes and allow the pressure to remain below 0° only the shortest possible time, as not only air may enter, but if it be the brine system and a leak exists, brine also will be drawn in.

How does a refrigerating engineer know when the condenser pressure and back pressure of his plant are right for economical operation ?

With an engineer who is familiar with the underlying principles on which the efficiency of refrigerating systems depends, it is largely a matter of judgment. Such judgment must be based on knowledge of the temperature of the condenser water, whether there is sufficient condenser surface for the compressor, and whether or not the condenser pipes are free from uncondensable foreign gases. With these things known to be right, condenser pressure for different temperatures of cooling water should be approximately as in the following :

TABLE.

1 gallon per minute per ton per 24 hours—							
Temperature of cooling water, degrees F	60	65	70	75	80	85	90
Condenser pressure, gauge, lb	183	200	220	235	255	280	300
Temperature of condensed liquid ammonia, degrees F	95	100	105	110	115	120	125
2 gallons per minute per ton per 24 hours—							
Condenser pressure, gauge, lb	130	153	168	183	200	220	235
Temperature of condensed liquid ammonia, degrees F	77	85	90	93	100	105	110
3 gallons per minute per ton per 24 hours—							
Condenser pressure, gauge, lb	125	140	155	170	185	200	215
Temperature of condensed liquid ammonia, degree F	75	85	90	93	95	100	105

Similarly, the evaporating or back pressure within the expansion coils of a refrigerating system depends upon the temperatures on the outside of such coils, i. e., the air or brine to be cooled. For average practice, back pressures for the production of required temperatures should be approximately as follows :

TABLE.

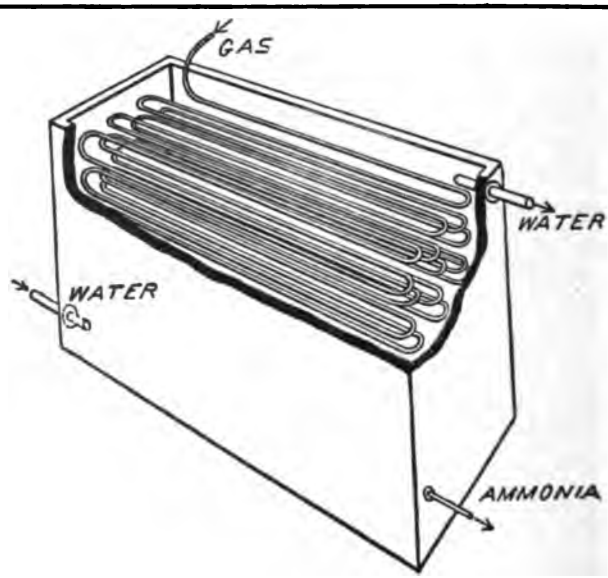
Temperature of room, degrees F.		10	15	20	28	32	36	40	50	60
Back pressure, gauge, lb	7	10	12	15	22	25	27	30	35	40
Temperature of ammonia, degrees F	13	10	5	0	8	12	14	17	22	26

Which is the more efficient, the submerged or atmospheric condenser ?

The latter ; it requires less water but more pipe.

Describe the submerged type ?

Submerged condensers are those in which the ammonia coil is immersed in a tank of water. The counter current principle of cooling is employed, viz., the hot gas enters at the top and leaves as a liquid at the bottom. The cold water enters at the



Submerged Condenser. In this type of condenser the counter current is naturally obtained as the water entering at the bottom will rise to the top as it warms up. The gas is admitted at the top and the liquid is drawn off at the bottom.

bottom and overflows at the top of the tank. Thus the cold water comes in contact with the coolest part of the coil and the warmest water with the hottest part of the coil.

How much larger amount of water is required for a submerged condenser ?

Submerged condensers should be allowed at least 20 per cent. more water than is required for an atmospheric condenser.

What is a disadvantage of the submerged condenser ?

Where there is abundance of water a submerged condenser might be advisable if it were not for the disadvantage that the pipes being in water are not easily inspected or cleaned ; a leak, too, may not be noticed, as the water will absorb the ammonia and no bubbles will rise to the surface. There is also liability to form along the pipes a film of warm water containing bubbles of air which interferes with the efficiency of the process.

Why is the submerged condenser not a favored type ?

There are several reasons why this style of condenser is not usually economical. A large amount of water is required, because it is impossible to have all the water come in contact with the coils, owing to the large amount of space between them, and the inability to accurately control the movement of the water. The circulation of the water is always upward, but only a fraction of it passes directly over the pipe.

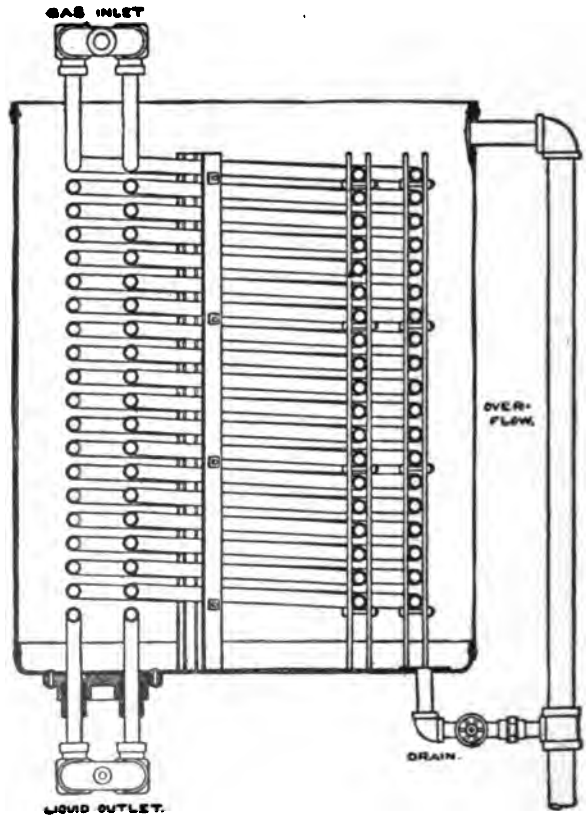
It is difficult to obtain efficient circulation, and frequently air bubbles form on the pipe and layers of warm water lie about some of the sections, thus insulating them and retarding the transference of heat. This condition makes it necessary to use agitators of some kind, but the degree of movement must be such as not to interfere with the counter current principle.

Why is the submerged condenser used on shipboard ?

It is the type most convenient for marine service. On the other hand it requires a much larger amount of cooling water, making its use out of the question where water is scarce or expensive, and the weight of a tank containing water as well as coils makes a strong support necessary, and in this country its use is limited to special requirements and localities.

What variation in the form of the submerged condenser is occasionally used?

Shell types of condensers may be called reversed submerged condensers. Instead of surrounding the coil of pipe containing



Submerged ammonia condenser. The gas passes through the double coil, which is surrounded by water circulating through the tank. The liquid is drawn off at the bottom.

ammonia gas with water, the water is conducted through the pipes which are surrounded by the ammonia gas. The shell is

strongly made to withstand high pressures, and the water pipes are securely fastened. All expansion and contraction due to the varying temperatures is taken care of in the coil itself. The cold water enters at the bottom, and flowing upward, meets the hot gas, while the gas enters at the top and flows downward meeting the cold water. This condition fulfills all the requirements of the counter current principle. It is worthy of note that with this type of condenser the liquid ammonia may be stored in the bottom and taken direct to the expansion valves as needed. The shell has no insulation, and any heat that may be radiated into the air decreases the amount of water required in the coils. The transference of heat in the condenser is not rapid, but any kind of water may be used, and if sufficient radiating surface is provided satisfactory results can be obtained.

Describe the Hendrick surface condenser.

It is a heavy iron shell provided with water coils. The water circulates through the latter so that the gas entering the shell at the top is condensed and falls to the bottom, the lower portion being used as a liquid receiver. Its working is the exact reverse of the submerged condenser, and its action is said to be very efficient.

What good points must a condenser have ?

It should possess the following features :

1. Condense the ammonia gases quickly, thereby reducing the pressure.

2. Cool the ammonia as near as possible to the temperature of the cooling water.

3. The construction of the condenser such that any part can easily be replaced.

If a condenser lacks one or more of these qualities, it will greatly interfere with its working, and reduce the efficiency of the whole plant. If, for instance, it is badly designed or too small for its work, so that it cannot condense the ammonia gas

quickly, the gas which is constantly discharged into it, by not getting condensed, will raise the pressure. This naturally means more power for driving the compressor, and therefore, higher running expense. Further, if the construction is such that the water surrounding the pipes cannot extract all the heat, the liquid ammonia will be discharged into the refrigerator at a much higher temperature than it would have if the condenser had been properly designed. The lower the liquid ammonia is cooled in the condenser, the more heat it can absorb.

Should a covering be placed over an atmospheric condenser ?

It would be well to protect it from the sun but the cover should not interfere with the free circulation of air.

How does a leak in a condenser sometimes affect the ice ?

If grayish ice is formed and submerged condensers are used, it will be well to look for a leak in the condenser.

How may gas leakages be detected ?

If through leakage in the coils or other parts of the apparatus, water or brine becomes mixed with the ammonia, it may be detected by drawing off a small amount of the liquid in a test tube or other small receptacle. The ammonia will evaporate, leaving the water or brine in the tube, from which it is easy to determine the proportion present.

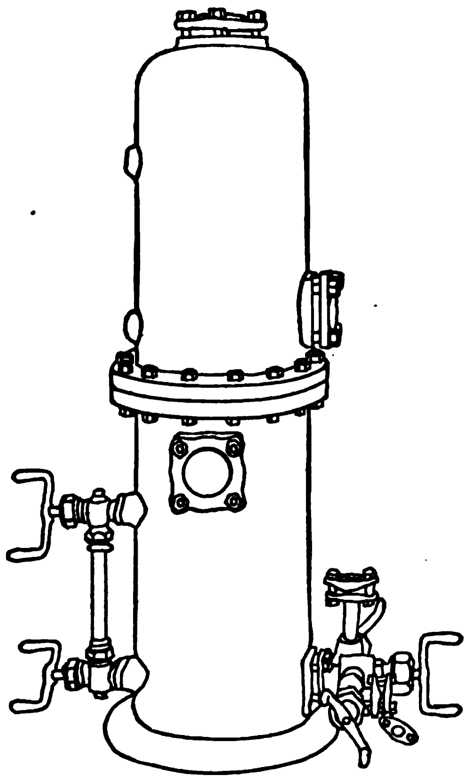
Great care should be taken to prevent the waste of ammonia through leakage. If the gas escapes into the air it is easily detected by its odor, but if the leak is in a submerged coil it is necessary to test the solution with which it is surrounded.

How may chemical tests be applied ?

In order to do this, certain chemicals are necessary. For example, phenolphthalen causes a bright pink color, Nessler's solution a yellow or brown color, and red litmus paper when dipped into the solution turns blue when ammonia is present.

How should the condenser coils be tested before they are used ?

Whether submerged, atmospheric, double pipe or shell type condensers are used, all pipes, fittings and connections must first



Oil trap which is "fitted up" to be used also as an ammonia regenerator.

be cleaned and freed from all scale and mud, which is best done with scrapers made of old files, or with strong steel brushes.

After cleaning the coils should be tested by air pressure and under a vacuum.

Is the air test sufficient ?

All pipes, seams and joints should be tested with sulphur sticks while the coils are filled with ammonia, and mark carefully all leaks with chalk. Leaks on flange joints may be stopped by pulling up the bolts, and leaks on pipes can be repaired with clamps. But leaks on screw joints make it necessary to disconnect the fitting, cut the thread over and make a new joint, and for this, as well as for exchanging split pipes, the condenser must be pumped out and disconnected.

How are sulphur sticks made ?

Melt in a tin can or ladle, ordinary sulphur—brimstone—being careful that it does not get too hot, or else it will burn, which can be prevented by having the can or ladle covered to keep the air out. Cut thin sticks of wood, about one-quarter of one inch thick and 6 to 9 inches long, or strips of cardboard of same size, and dip the ends into the molten sulphur, which must be repeated till the coating on the sticks or strips is about one-sixteenth of an inch thick. Have plenty of them for ready use, as they are very cheap, and come in handy all the year round.

For testing, light the end of the sulphur coating and move a distance of about one inch along all pipes, around all fittings, joints and valve stuffing boxes. As long as no dense smoke is noticeable, there is no leak, but as soon as smoke ensues while moving along some part of the pipework, investigate carefully whence the smoke comes, and you will soon find the ammonia leak, no matter how small it is.

Is this a very efficient test ?

Pipework which has been considered absolutely tight after testing with air pressure or with ammonia by smell has been found leaky by the sulphur test. But this method can not be applied as long as very bad leaks exist which can be heard by blowing or detected by smell, because the surrounding atmosphere is then filled with ammonia, and smoke is produced where-

ever sulphur is burning. The sulphur test is the most reliable and never-failing method for testing everything which contains ammonia.

Does the exterior of the condenser coils require special attention ?

One of the first points to be kept in mind in the operation of a refrigerating plant is cleanliness, and special attention should be given to the surfaces of the condenser to obtain the best efficiency.

The necessity of keeping the condenser free from air or other foreign gases has already been mentioned. In addition to this all deposits should be regularly removed from the outside surfaces.

How should the coils be cleaned from time to time ?

It is necessary to blow out the deposits from the water, and when this is done a water pressure of 400 pounds per square inch will show corrosion or bad places, so that it is advisable to apply it.

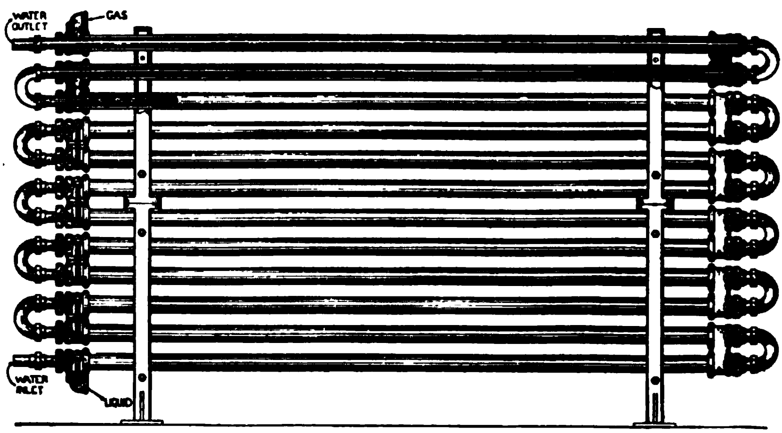
What is the double-pipe condenser ?

This type of ammonia condenser has only come into use during the last few years, and in some ways has many advantages over both submerged and surface condensers. The construction is such that one pipe is placed within another, which pipes, at each end, are connected by special bends, so as to make two separate zig-zag sections of inner and outer pipes.

The ammonia gas is delivered in at the top and forced downward through the large outer pipe, while the water comes in at the bottom and is forced upwards through the smaller inner pipe. As the water does not come in contact with the atmosphere, after having done its work by cooling the gas it can be carried to any part of the building and used for other purposes. The life of such a condenser is of much longer duration than any other type, as the only pipes which can corrode and eventually give out are the inner water pipes. As the ammonia has no corroding influence on iron, the outer pipes will last indefinitely.

What are the advantages of the double pipe condenser ?

It is cleaner, there being no dripping water, consequently it can be placed in any room. Less space is required than for an atmospheric condenser of equal capacity. A greater efficiency is also claimed over other types of condenser because the temperature of the ammonia entering the condenser and that of the water leaving it are more closely equalized.



Double Pipe Ammonia Condenser. The gas enters at the top in the annular space between the outer and inner pipes, the liquid being drawn off at the bottom. The inner pipes are for the water, and thus the counter current effect is easily obtained.

Is the double pipe condenser very effective in working operation ?

On account of placing one pipe within the other the space allowed for the ammonia gas is very small, consequently the amount of gas surrounding the water pipes is also very small, and the heat is quickly extracted. This is a great advantage, as the quicker the ammonia gas gets cooled, and liquefied, the lower will be the pressure, and consequently less power required to drive the ammonia compressor. As the coldest water enters at the lower end of the coil section, where the liquid ammonia collects, by passing through this, the thin layer of liquid ammonia is quickly reduced to the temperature of the coldest water.

This means a considerable increase in the refrigerating efficiency, so that a double pipe ammonia condenser has many advantages over the submerged and open condensers. The atmospheric condenser, however, has the advantage in that the pipes are always open for inspection, and can be cleaned when necessary, and always kept in first-class condition. With a double-pipe condenser, where the water pipe is inside, these pipes cannot be so readily examined, but special provisions are made for cleaning out the pipes. It is, however, advisable with double-pipe condensers to examine the inner pipes thoroughly every few years.

What is a disadvantage of a double-pipe condenser if not carefully constructed?

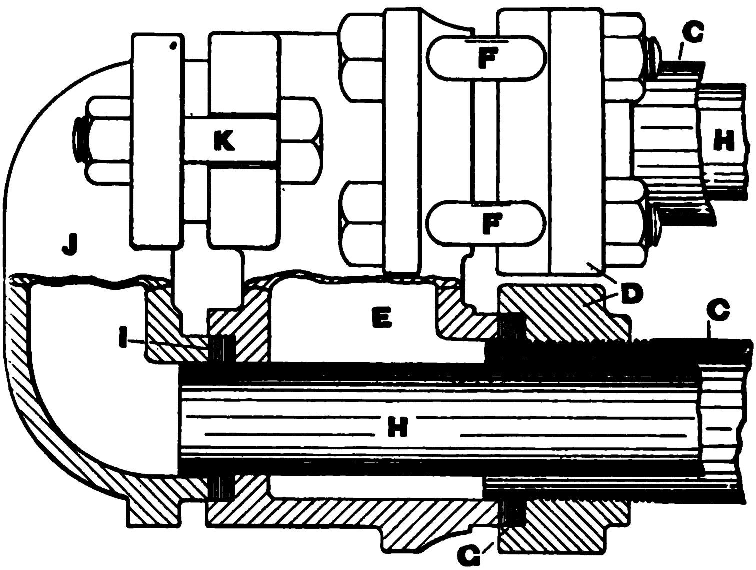
Although a small space between the inner and the outer pipe is of great advantage for the quick condensing of the ammonia gas, this small space has also its faults, as there is a tendency to make it too small for the passage of the gas.

How do the manufacturers of the Linde machine meet this difficulty?

The construction of their double-pipe condensers overcomes this defect. as by the peculiar construction of the condenser heads, when the ammonia gas enters the condenser it is divided and delivered into three pipes, which pipes at the other end are joined to get the gas thoroughly mixed before it is again passed through three other pipes. By repeating this action at each end all the gas is evenly cooled and quickly liquefied. Therefore though the condensers are also built of 2 inch outer and 1¼ inch inner pipes, by passing the gas through three pipes instead of one, the full area of a 2 inch pipe is sustained and the gas travels along with the same speed at which it is delivered to the condenser. Further, by dividing the gas into small quantities and by mixing it and bringing each separate part into contact with the cold surface of the water pipe, the gas gets cooled and condensed much faster, which means a further reduction in pressure.

What special point needs to be guarded against in a double-pipe condenser ?

They must be looked after in freezing weather, or the water pipes in them may freeze up and burst.



Double pipe condenser return bend the ammonia pipes C C are screwed into the flanges D, and to those flanges the casting E is held by the bolts F F, compressing the soft packing G. The inner pipes H H are for the water circulation, the joints being made tight by means of the soft packing rings I, around each end of the pipe, which are compressed by the return bend J and the bolts K.

Why is the outer pipe in a double pipe condenser varied in size ?

As the volume of the cooling water practically undergoes no change the inner pipe of a double pipe condenser is always the same size for its entire length, usually 1¼ inches. The condition of the circulating gas, however, greatly varies, and, as a result, the outer pipe is usually made larger at the entrance than at the exit. The ammonia gas enters at the top and is gradually

condensed as it proceeds toward the bottom, and as condensation progresses the volume decreases until all the gas is changed to a liquid. It is always desirable to confine the ammonia to as small a space as possible in order to facilitate the transfer of heat to the cooling water, but if the specific volume of the gas is high and the space is too limited, excessive friction may result. Some manufacturers use 2½ inch pipe for the first two or three rows for the ammonia gas, and then reduce the pipe to 2-inch.

Among the strong features of this type of condenser it may be mentioned that since the water is at all times under pressure it may be used for other purposes after leaving the condenser; the condenser is entirely self-contained and may be located in any convenient place, and the velocity of the cooling water may be closely controlled so as to obtain the highest efficiency at all times.

Describe the Wolf double pipe condenser?

These condensers are usually twelve pipes high. The two upper pipes are 2½ inches in diameter and the ten lower 2 inches. The waterpipe is 1¼ inches throughout. The use of large pipes at the top gives a wider annular space between the external surface of the waterpipe and the internal surface of the ammonia pipe, providing the greater space which is required for the gas when it first comes into the condenser, owing to its rarefied condition. As soon as the cooling influence of the water becomes effective and the ammonia becomes denser, less space is, of course, required.

What is a good way of cleaning double-pipe condenser coils?

They may be scoured out with compressed air, using a mixture of sand and water under 20 pounds pressure.

If compressed air is not available a steam jet may be used to operate the sand blast; in this case but little water should be mixed with the sand or there will be too much condensation of the steam.

Why does the amount of cooling water necessarily vary with the temperature required in the cooling rooms ?

Not only does the amount of cooling water required per ton vary with its temperature, but also with the cooler temperatures required and the condensing pressure encountered.

If, for example, a cooler is to be maintained at 20 degrees Fahrenheit, a back pressure of 15 pounds is to be carried, resulting in 0 degree ammonia within the expansion coils, and the head pressure be 145 pounds, only 0.75 gallon of cooling water will be required, provided it be sufficiently cool to rise 20 degrees in temperature and still be 10 degrees cooler than the temperature of the condensed ammonia corresponding to the pressure. Now, the temperature corresponding to 145 pounds head pressure is 82 degrees Fahrenheit, so that 82—30=52 degrees, the required temperature of the cooling water.

Why, if only one temperature is to be carried ?

Where there is only one temperature to be produced in the cold-storage compartments a back pressure is usually carried, such that the temperature corresponding to that pressure will be about 22 degrees Fahrenheit below that of the cooler temperature. Under average operating conditions the cost of the amount of expansion pipe required to allow of this range in temperatures balances up fairly well with the loss in efficiency that would be encountered if less expansion piping were installed and a lower back pressure carried.

Why do operating conditions change if varied temperatures are to be maintained in different rooms ?

Where several different temperatures are to be maintained with one back pressure no fixed rule can be followed, and each individual case must be figured out separately. If only a small per cent. of the total cooling work be low temperature, it is usually advisable to reduce the temperature range between the liquid ammonia and the surrounding air, making up for the

reduced range by the installation of inversely proportionately more pipe. In this case the expenditure of an abnormal amount of pipe in a small per cent. of the entire duty allows of an increase in efficiency of the whole plant.

How does this variation in temperature affect the piping required ?

While the necessity of producing a low temperature in a single box reduces the efficiency of the entire plant—or that part of it which is required to carry the low back pressure because of that low temperature—there is a slight compensation for the decreased efficiency in the way of decreased first cost of expansion piping for the higher temperature boxes. The ammonia pressure and temperature being reduced in order to cool the low temperature box may be sufficiently colder than the high-temperature boxes as to allow the pipe surface in the high-temperature boxes to be reduced often as much as 50 per cent. This condition would obtain when the difference between the ammonia and the high-temperature boxes becomes 44 degrees Fahrenheit.

What is an important objection to atmospheric condensers ?

Their action is sluggish when the weather is warm and the humidity is great.

What is the liquid receiver ?

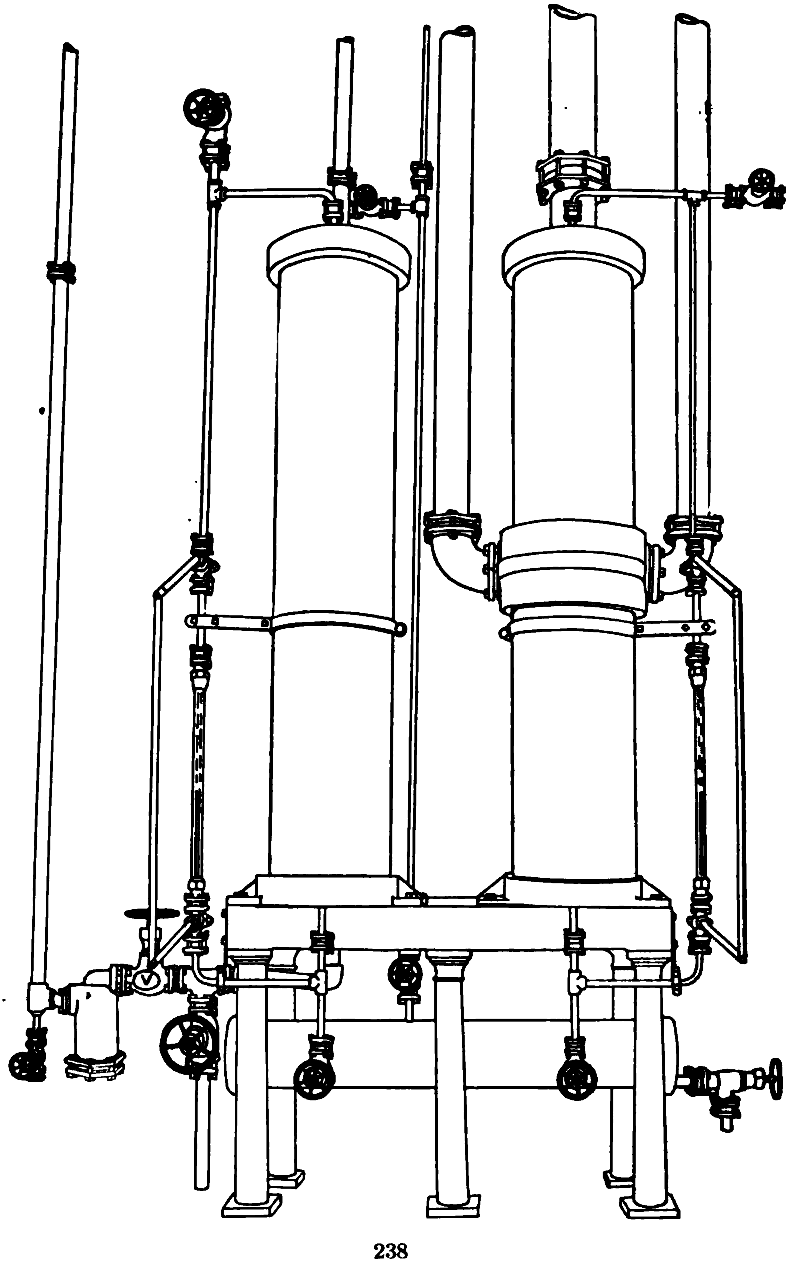
A vertical or horizontal cylinder to hold the ammonia as it comes from the condenser.

How high should the liquid receiver be tested ?

Up to 1000 pounds pressure.

What is the purpose of the liquid receiver ?

In a refrigerating plant it answers the same purpose as the storage battery of an electric light plant, serving as a sort of balance wheel, and reserve in case of emergency. Another valuable service of the receiver is in acting as an oil trap, and for this purpose it should be supplied with suitable glass gauges and a valve for drawing off the oil at the bottom.



What should be the capacity of the liquid receiver?

About half a gallon per ton of refrigerating capacity. In case, however, it is ever to be used as a storage vessel for all the ammonia in the plant during repairs, it should be large enough to hold the whole charge twice over. It is a great convenience to be able to put the entire charge of ammonia in the receiver in case of emergency. With a large receiver, which is not too full, an expansion coil can be repaired without shut down in the plant and the plant is much easier to operate when starting up.

A rule given by Siebel is that for an absorption plant, the receiver should at least hold enough liquid ammonia to bring the poor liquor at the bottom of the retort up to 73 to 77 degrees F. In a compression system, he would have the receiver which is placed between the condenser and the expansion valve hold 0.5 gallon of liquid for each ton of refrigerating capacity.

Where should it be placed?

The ammonia receiver should be placed in a cool place, preferably alongside the freezing tanks, so as to reduce the temperature of the liquid as low as possible. It is also good practice to put in a liquid cooler to cool the liquid on its way between the receiver and the evaporating apparatus.

How is this liquid cooler constructed?

A very efficient liquid cooler may be made up in the same manner as a double pipe condenser. The liquid on its way to the expansion coils is led through the inner pipes while the return gas from the expansion coils passes through the annular space between the pipes on its way back to the compressor.

The discharge pipe of the compressor, as shown on opposite page, is led through the oil trap at the right, depositing the oil therein. The oil is drained off into the oil drum, from which it can be taken periodically. The receiver at the left is also connected to this oil drum, thus any oil that may be carried through the condenser can be drained off into the drum. Both receiver and oil trap drains are provided with stop valves, so they can be shut off until the oil shows in the gauge glasses.

What is a common mistake in locating the liquid receiver ?

Placing an ammonia receiver in an engine room is in the same line as running distilled water mains through the furnace under the boilers. It simply evaporates part of the liquid and drives gas back into the condenser to be recondensed. Such connections make it necessary to use larger condensers and more condensing water, and, in addition, the liquid ammonia goes into the evaporating system carrying the full quota of heat, thereby reducing its value to a minimum.

How is it best arranged ?

With gauge glasses, and gauge cocks which will close automatically in case of the breakage of the glass.

How is the purge valve arranged ?

If the liquid ammonia receiver be placed in a vertical position it is customary to place a purge valve in the bottom for drawing off oil or other impurities. The supply of liquid to the evaporator being taken off at a short distance above the bottom, say 4 to 6 inches.

Can we determine the refrigerating effect of the liquid ammonia by the amount leaving the condenser coils ?

The liquid in passing from the condenser coils to the receiver may take up heat from some outside source, which would reduce its refrigerating capacity, also in its passage from the receiver to the evaporating coils its temperature may be raised, for this reason, all pipes, as well as the receiver, should be well insulated.

What should be the temperature of the liquid ?

The temperature at which the ammonia enters the evaporating coils should be that of the water used for condensing purposes.

How can the charge of ammonia be kept in good condition ?

By the use of an ammonia distiller or regenerator.

What are its advantages ?

This apparatus, when installed in connection with a refrigerating or ice-making plant, enables the operator to redistill the entire charge of ammonia without drawing it from the system and without interfering for one moment with the continuous operation of the plant ; if used regularly in usual operation it takes the place of the ordinary oil separator and keeps the ammonia at all times perfectly pure and anhydrous—a condition impossible to obtain without its use, and one which is absolutely essential to the highest efficiency of a refrigerating machine.

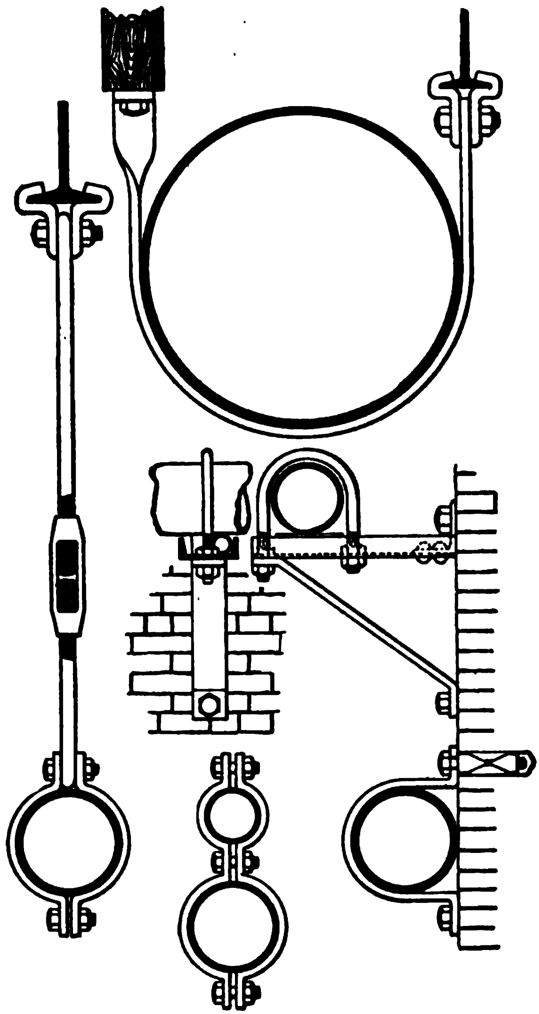
Describe its workings.

The liquid ammonia, with its impurities, is let into the distiller from the liquid receiver, oil trap, or direct from the condenser, through the liquid inlet "A." (See figure on page 186.) The inlet valve should be left open until the glass gauge shows that the reservoir is slightly more than half full. The ammonia relieved of the pressure which has until now kept it in the form of a liquid, begins to expand into a gaseous form, the horizontal position of the apparatus affording, when the reservoir is half full, an evaporating surface of over six square feet, which is many times greater than in a vertical oil separator.

The ammonia vapor passes out through the pipe "B" into the liquid trap, which is designed to prevent the possibility of any liquid being carried over into the compressor. This trap is connected by the pipe "C" with the suction line to the compressor.

How is the distillation hastened ?

In order to accelerate the vaporizing of the ammonia a steam pipe is provided for raising the temperature in the distilling



Several methods of suspending pipes from ceilings, walls and beams.

apparatus. The steam enters through the pipe "D," which, as will be seen, is inserted in another and larger pipe. A drain marked "E," is provided for taking care of the water of condensation. Care should be taken that the temperature of the liquid is not raised above 60 degrees to 70 degrees F., and to this end the pressure recorded on the pressure gauge should not be allowed to go above 90 to 100 lbs. The temperature corresponding to a pressure of 90 lbs. is approximately 60 degrees, and that is high enough to make the evaporation quite rapid and at the same time is low enough to prevent the vaporizing of any oil or water contained in the liquid ammonia.

How can the engineer tell when the operation is finished?

By observing the pressure gauge at the end of the apparatus, the operator can tell when all the liquid which will evaporate has been vaporized. The outlet valve "F" on the suction line to the compressor should be left open until the pressure in the reservoir is reduced to that in the suction line to the machine, as indicated by the suction gauge in the engine-room.

What should then be done?

This valve "F" should then be closed and the remaining liquid, consisting of oil, water and other impurities, discharged from the apparatus through the drain pipe "G," which, it will be observed, is placed at the lowest point of the head. A drain, marked "H," is provided for draining the liquid trap of any impurities that may have been carried along with the vapor from the reservoir of the apparatus. A safety valve is provided in a by-pass around the liquid trap so that in the event that the valves are not properly opened to relieve the pressure there will be no danger of accidents.

The blow-off of the safety valve is connected to the pipe leading to the suction of the compressor, thus no gas escapes to the atmosphere.

How is water usually obtained for ice making ?

Ice is usually made from the exhaust steam of the compressor or of the generator.

How is it necessary to treat the water in a compression plant ?

It must be freed from the oil of the cylinder by use of steam filters, using sponge, silicate, or bone charcoal.

Does the oiling of a compressor or ammonia pump require careful attention ?

Yes. No more oil should be used in the steam cylinder than is absolutely necessary. From two to four drops a minute will answer for most engines, if the oil is good.

Should special care be used in looking after oil ?

The oil should be of such a nature that it is not saponified by contact with the ammonia, as such a change would cause a thick coating on the inside surfaces of the pipes and other parts of the apparatus.

How is saponification brought about ?

Animal and vegetable oils are formed of a fatty acid and glycerine, which separate when exposed to a high temperature. If soda or potash be present the fatty acid combines with it and forms soap.

How often should the oil separator be examined ?

Oil should be drawn off from the separator about once a week, or oftener if there is danger of its being carried over into the condenser. If the oil is of the proper quality it should be in practically the same condition as before using, and may be used over again after being allowed to stand until the gas has escaped from it. If it shows any signs of having been affected by the ammonia its use should not be continued.

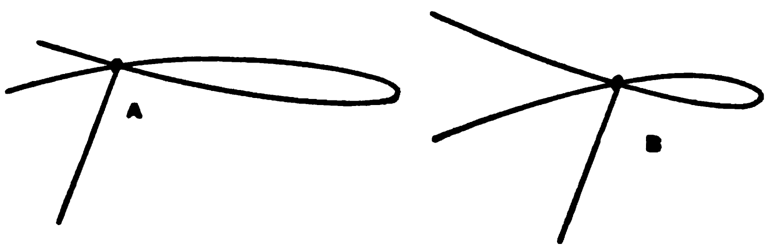
Don't forget the oil separator; it should be constantly drained of water and oil.

Why are animal and vegetable oils unfit for refrigerating use?

Because they form with alkaline substances, such as ammonia, a soapy emulsion, and by steam are decomposed into fatty acids and glycerine. Vegetable oils are also liable to dry or gum.

What kind of oil does this make necessary?

Mineral oils which are composed of carbon and hydrogen; they are the only ones that should be used in cylinders.



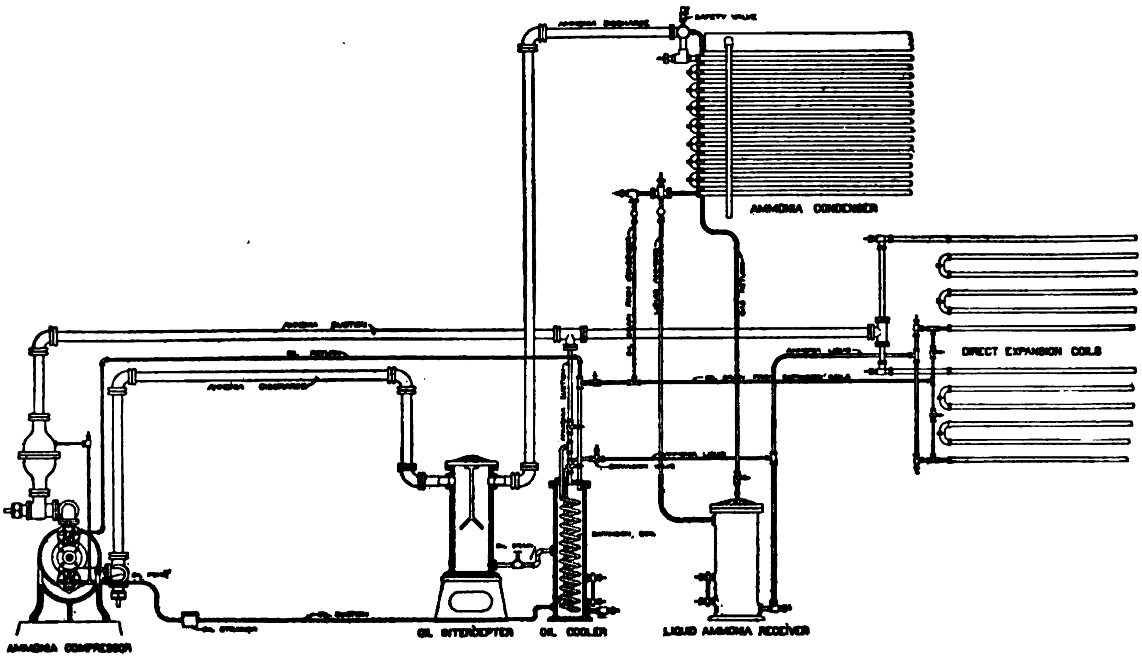
Piano wire loops for testing the viscosity of oils.

How may we detect the presence of animal matter in oil?

Take an ordinary 4 oz. bottle and fill it about one-quarter full of the oil to be tested, and add about two teaspoonfuls of powdered borax. Shake the bottle with its contents for a few minutes, and if a soapy deposit forms the oil contains animal matter and should not be used in an ammonia compressor.

How may we compare the viscosity of different oils?

Make a loop of fine piano wire as shown in the illustration and pass the ends of the wire through a small eye formed on the end of another wire. Now slip the eye up toward the closed end of the loop, thus drawing it together, and dip the loop into the oil to be tested. A fine film of oil will bridge over the loop, and by sliding the eye so as to allow the loop to open, we can note how far the eye can be drawn out before the film will break. The film of oil which allows the loop to be opened the farthest is the most viscous oil.



System of cooling the oil for ammonia compressors. The oil is circulated by the oil pump, through the stuffing box, and from there it passes through the return pipe to the oil cooler, which is provided with an expansion coil through which a small amount of ammonia is circulated. The expansion of the ammonia cools the oil and it is again circulated by the pump.

How should economy be exercised in using oil ?

By collecting the surplus in drip pans so that it may be filtered and used over.

What is the advantage of the oil cooling system of the Triumph Ice Machine Co. as shown on opposite page ?

The arrangement of an oil cooler in the ammonia system constantly provides a cold supply of oil for the stuffing box and cylinder of the compressor. The employment of this cooler will overcome the annoyances and loss experienced in many plants from the escaping ammonia at the stuffing box, as a cold supply of oil will maintain a moderate temperature in the stuffing box, cooling the piston rod and preventing the excessive wear on the packing, which results from a hot rod.

How is it described ?

The design is continuous, preventing the wasting of oil, which is an important item to be considered when economy is desired. It will be noticed that the oil cooler contains a spiral coil located in the expansion system, and through the aid of an expansion valve placed immediately above the cooler, the proper temperatures may be carefully maintained. A gauge is fitted to the cooler so that at any time the attendants may be informed as to the supply on hand. Such oil as may have by chance entered the expansion coils can be dropped in this receptacle and all accumulated foreign matter may be drained off from the valve located at the extreme bottom. An oil strainer is placed directly before the compressor, which precludes the possibility of any solid matter entering the machine.

When it is desired, the oil may be removed from this cooler and same converted into an ammonia purifier or still. At such times as it is found necessary to purify the ammonia in the system, a live steam line may be attached, and with the aid of a hose spraying on the cooler and heating same slightly, perfect distillation of ammonia can be procured.

What is a rough estimate of condenser water needed?

If it enters the condenser at 60 and leaves at 90, one gallon per minute for each ton of ice making capacity in 24 hours, while if it enters at 60 and leaves at 75 two and one-half gallons will be required.

Does piping often give way without some warning?

There have been but few accidents in the history of refrigeration, where the piping has given way and allowed the ammonia to escape in any considerable quantity.

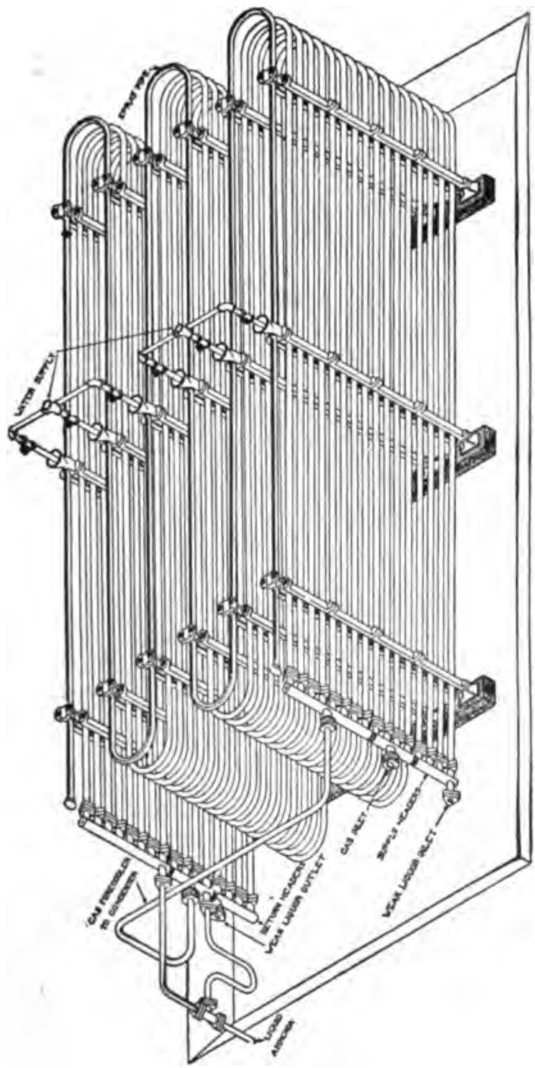
The first indications are usually small holes in the pipe which allow the ammonia to flow out in a small stream in gas or liquid as the case may be.

Is there a large margin of safety in the piping used for condensers?

The average pressure carried on a condenser is from 150 to 185 pounds per square inch, and as common wrought iron pipe two inches in diameter will stand from 1800 to 2500 pounds per square inch before rupture, it is safe to say that under most conditions there is a factor of safety of nine times the maximum pressure required for heavy condensing purposes.

What is an average condition of wear?

In calipering a piece of pipe removed from a condenser after a service of six and one-half years, a deterioration of 4–100 of an inch from its original thickness of 20–100, or a loss of about 20 per cent. was found. Considerable pitting was noticed and one small hole was found corroded clear through the pipe, which allowed the gas to escape, bringing it to the attendant's notice, although it was not enough to prevent the engineer closing the valves. A blanket or gunny sack thrown over a leak of this kind with a small stream of water flowing over the cloth will hold the gas in check and make getting to the leak much easier work.



The Vogt Atmospheric Zigzag Coil Condenser.

The condenser is built in three sections. The top section is the condenser proper; the second section is the fore cooler, in which the gas is partially cooled before entering the condenser; the third section is the weak liquor cooler. The arrangement of the water distributing pipe is clearly shown in the cut.

What are two very important points in machinery using ammonia or steam?

Perfectly constructed and operating valves and correct alignment of the machine.

Are tight valves very important?

It is necessary in a refrigerating plant to have valves which are reliable, as on these depend the saving of the ammonia. If some part of the system has to be opened for inspection, the valves when closed must not let any ammonia vapors pass. If they do, it not only means a waste of money, but it is also very annoying to the engineer who has to work in these vapors. Beside being perfectly tight, the valves should be accessible at all times, without having first to unscrew a gland before one can get at the spindle.

How may a rusty coupling be unscrewed?

To unscrew a large pipe coupling that has been screwed together with a greater force than can be had to unscrew it, or that has become rusted fast, a good plan is to heat the coupling by building a fire around it, or better still, turn a jet of steam on it. At the same time try to unscrew with chain tongs. The coupler will heat sooner than the pipe, and will expand away from it.

Another and unfailing method is to heat the joint to a low red heat, and then pour cold water over the pipe close to the coupling or fitting. The heating of the joint causes both fitting and pipe to expand, and the sudden cooling of the pipe will contract it so suddenly that any cementation in the joint will break. The joint will readily open up so that the fitting can be unscrewed even by hand if it were not too hot. If this process is done quickly the largest and hardest joints may be separated with great ease.

CHEMISTRY AND DISTILLATION OF WATER.

Why is pure water very unusual in nature ?

It is the greatest natural solvent known, hence it is rarely found pure. Water is capable of absorbing nearly every gas and vapor with which it comes in contact.

Is the quality of boiler feed water important ?

Not many years ago the chemical composition of water for industrial purposes was considered to be of little importance. Water was water for the factory man, if it would flow through a pipe in sufficient quantity. But that attitude has changed. At the present day when business competition is so intense, when every detail of cost is subjected to such careful scrutiny, the quality of the water, the raw material of the trade, has become of great importance. The far-seeing manufacturer locates his refrigerating plant with special reference to the available water supply; he considers the effect of the supply on his boiler and on his condenser tubes; and he adapts the type of his machinery to the quality of the water.

Is it best to treat water before it enters the boiler ?

Treating feed waters inside of the boiler is a practice of many years' standing, but, in the light of recent progress, is not to be commended. A boiler, generating steam, has all that it can reasonably be expected to do without being called upon to perform the functions of a chemical laboratory. The external method of treating feed water, chemically or mechanically, is being adopted by many progressive plants in this country.

Why is a water analysis sometimes misleading?

To determine its value for steam or drinking purposes its quantitative analysis should be known as well as the qualitative; also its bacteriological condition.

What solid matters are frequently found in water?

Animal life, organic matters, such as sewage, decayed vegetable and animal matter, poisonous metals, magnesia, lime, carbonates, sulphates, alkalies, earthy salts, chlorine, bromide combinations, etc., are found in variable quantities.

How may the presence of various foreign matters be detected?

To test water in its natural state and before boiling, insert blue litmus paper. If the water turns it red it is carbonated, and contains carbonic acid. If, after boiling, it does not turn the blue paper, the same is true, or, if after turning the paper red, the blue color may be restored by slight heat. Water, which gives out a sickening odor, and shows a black precipitate with acetate of salt is sulphurous, containing sulphureted hydrogen. Water which gives a blue precipitate, with yellow or red prussiate of potash through the addition of a few drops of hydrochloric acid, is chalybeate, containing carbonate of iron.

Water which will, after boiling, restore the blue color to litmus paper, is alkaline.

Water which shows none of the above properties in a marked degree, or leaves a large residuum after boiling is saline, and contains salts.

Is water which will stand these tests always fit for drinking?

Water may be clear and sparkling and satisfactory by all the foregoing tests, but still not "potable," that is, fit for drinking, for the reason that it may contain very objectionable bacteria which can only be detected by microscopic examination.

How can such water be made suitable for drinking purposes?

Only by boiling; the high temperature destroying any organic life that it may contain.

What water is most satisfactory for refrigerating purposes?

Water for use in the ammonia condensing apparatus is preferred when taken from springs or deep wells, for it is much colder than surface water, hence much less is required. Water from a considerable depth is almost constant in temperature, generally from 50 to 56 degrees the year round, while water from rivers, ponds and streams ranges from 32 degrees in winter to 85 degrees in midsummer. The colder the water used in the condenser, the less power it requires to drive the machinery. For refrigerating machines an allowance of about 1½ gallons per ton refrigerating capacity, and on ice plants 3 to 4 gallons per ton, dependent upon the temperature, is necessary.

How is the purity of water determined?

Water is not pure if it becomes turbid or opaque by the following tests:

Baryta water indicates the presence of carbonic acid.

Chloride of barium indicates the presence of sulphates.

Nitrate of silver indicates the presence of chlorides.

Oxalate of ammonia indicates the presence of lime salts.

Sulphide of hydrogen slightly acid indicates the presence of either antimony, arsenic, tin, copper, gold, platinum, mercury, silver, lead, bismuth or cadmium.

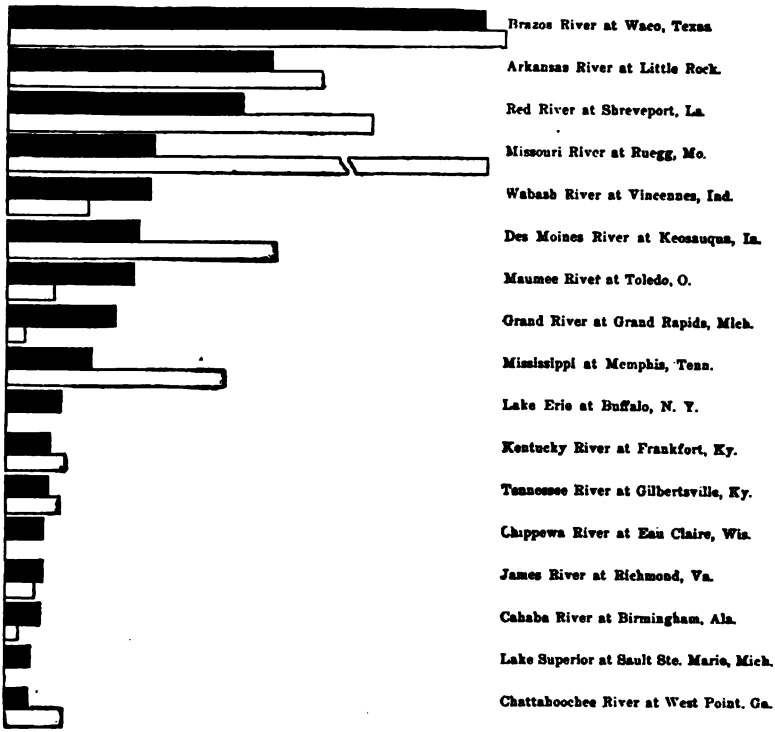
Sulphide of ammonia, alkaloid by ammonia, indicates the presence of nickel, cobalt, manganese, iron, zinc, alumina or chromium.

Chloride of mercury or gold, or sulphate of zinc, indicates the presence of organic matter.

Chemical tests will not reveal the presence of bacteria, it requiring microscopic examination for their detection.

Is there a considerable amount of dissolved and mechanically suspended solids in river water ?

The black lines in the diagram on this page represent the amount of dissolved solids, or the salts, while the other lines show the amount of suspended solids, or the mud.



By comparing the rivers of the Mississippi valley with those of the Southern Atlantic Coast, it is seen that the averages of the results for thirty rivers in the Mississippi basin are, dissolved solids 260 parts and suspended solids 300 parts per million ; similar averages for rivers in the Southern States are dissolved solids 80 parts and suspended matter 120.

What does this diagram mean in practical working?

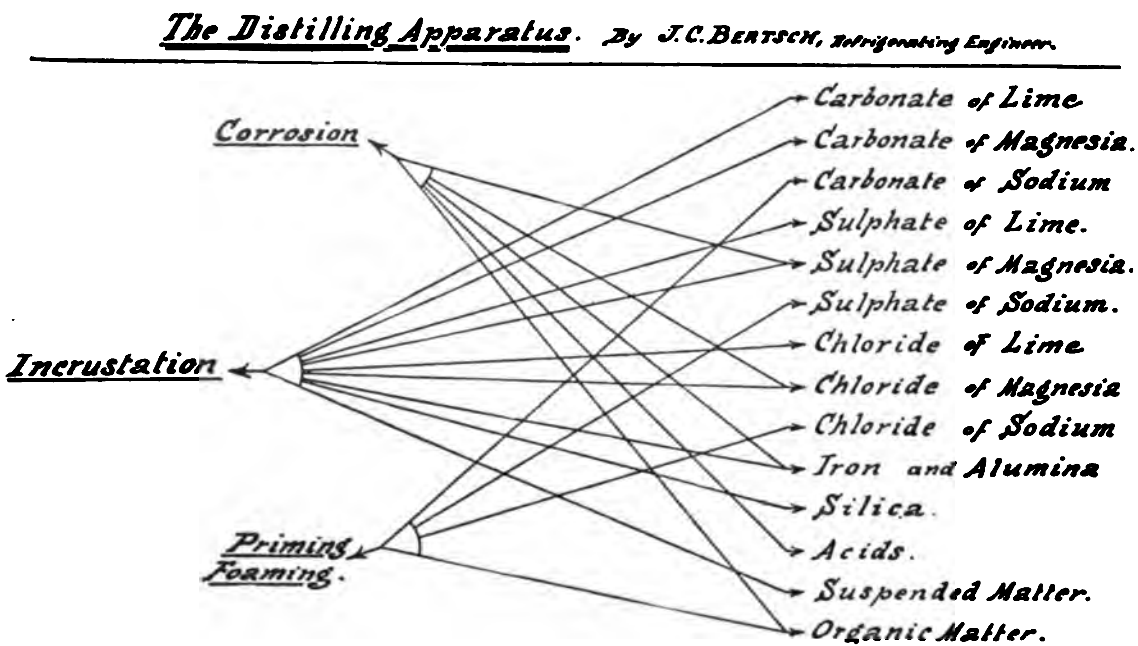
It means that the users of boiler water in some localities pay much more than the manufacturers in others, per ton of refrigerating duty, for boiler compounds, boiler repairs, boiler cleaning, idle machinery, and loss of heat efficiency.

What is a simple chemical test for chlorides in the water supply?

There is an easily made test which should be of considerable help in the efficient selection of water supply. Ordinary salt, sodium chloride, seldom or never exists in a natural water supply without being accompanied by magnesium chloride, which salt causes pitting and corrosion in the boilers and condensers and often leads to serious trouble. As a general rule, it may be stated that if the total chlorides exceed 10 grains per gallon, the water should not be used for these purposes.

An estimate of the total amount of chlorides in a water may be made, approximately, by the use of the following solution:

Dissolve 4.79 grams of nitrate of silver in a liter of distilled water. The weighing can be done by the druggist where the salt is bought. The solution should be kept in a bottle of dark color to exclude the light. Another solution, about an ounce, of bichromate of potash is made up. Then 58 cubic centimeters of the water to be examined is put into a graduated glass cylinder capable of holding 100 cubic centimeters and to this is added a few drops of the bichromate solution. The nitrate of silver solution is poured in slowly and the cylinder shaken all the time. The point at which the red color is permanent is noticed and the difference between the number of cubic centimeters of liquid contained in the graduated glass and the quantity of water taken, 58 cubic centimeters, will give approximately the quantity of chlorine present per gallon in the water to be examined. If this exceeds 10 grains per gallon, the water is not fit for use, as it will cause pitting and corrosion.



The chemicals named at the right of this interesting diagram exhibit, by the cross lines, their effects when introduced into steam boilers.

What is the composition of boiler scale?

In sea water it is usually sulphate of lime; in river or lake water, carbonate of lime.

Are the calcium compounds soluble in water?

Calcium bicarbonate ($Ca\ C_2\ O_6$) is very soluble in water, but when the water reaches the boiling point, the carbon dioxide is driven off and calcium carbonate ($Ca\ C\ O_3$) is practically insoluble in water. Magnesium bicarbonate is reduced to the simple carbonate in the same way, both forming scale.

Is boiler scale always objectionable?

A very thin scale may be a protection to a boiler from corrosion; beyond this, however, it retards the transmission of heat and may in this manner do no little harm.

What is the best way to prevent its formation?

By a feed water heater which may be cleaned at proper intervals. Some scale will form, however, and must be removed occasionally by suitable tools.

How is the question complicated as the pressures run higher?

The higher the boiler pressures, the greater the danger from scale and overheating.

How should oil be gotten out of the boiler?

By the surface blow usually.

What is a good plan with both marine and inland boilers?

To open the bottom blow at intervals and thus get rid of the sludge.

Are oils used for preventing scale?

Crude petroleum and kerosene oils are sometimes used but require care.

To what is pitting in a steam boiler due ?

Probably to electro-chemical action.

How is the electro chemical action neutralized to a considerable degree ?

By the use of pieces of zinc, which must not be used, however, if the boiler is intended for distilling purposes. Some engineers prefer to use soda and thus keep the water alkaline.

How is the zinc used ?

In slabs weighing from 8 to 12 pounds ; the pieces are suspended in baskets or attached to the sides of the boiler.

How many should be used ?

The number varies greatly with the judgment of the engineer and the size of the boiler.

How large an amount of solids is usually found in sea water ?

About 5 ozs. per gallon, or 2 pounds per cubic foot.

What does it consist of ?

Chloride of sodium, 76%.
Chloride of magnesium, 10%.
Sulphate of magnesium, 6%.
Sulphate of calcium, 5%.

Are these substances found to any extent in lake and river water ?

The composition of fresh waters is quite variable. Carbonates of calcium and magnesium and smaller proportions of their sulphates are most often met with.

What are three important points to observe in boiler management ?

1. A full supply of steam, with little variation of pressure should be the aim of the fireman.

2. Sudden chilling of the heating surfaces should be avoided as much as possible.

3. Fresh water in the form of steam should not be wasted.

How is the efficiency of a boiler roughly estimated?

By finding the weight of water evaporated into steam per pound of coal; this may vary from six or seven pounds to perhaps as high as eleven pounds of water to a pound of coal.

Where does loss of boiler efficiency largely take place?

Much of it takes place in the furnace and is caused by poor firing and imperfect combustion.

How may the loss be reduced to a minimum?

The boiler should be of good design, the air supply both above and below the grate be properly regulated for the fuel used, and more than all the fireman should work with ceaseless care and diligence.

Why must there necessarily be a waste in the chimney gases?

In order to secure a satisfactory draft the products of combustion must be discharged into the chimney at about 400° temperature.

What is the utilization of fuel values ordinarily?

A pound of good coal contains 13,000 or 14,000 heat units. Of this we manage to make useful from 7,000 to 11,000 units.

How much coal is required for the boiler of a non-condensing engine?

Three pounds per horse power per hour, as against 1¼ lbs. in a condensing engine of higher efficiency.

What are the principal points relating to economy in steam boilers?

1. Economy in coal.
2. Economy in weight of boiler.
3. Economy in first cost.
4. Economy in maintenance and total life.

Is it possible to combine all these features in any one make?

No, the decision is always a compromise between the four, the first one, usually, however, having the most weight.

Are there different ways of measuring the pressure of steam?

In the practical operation of a boiler or in making calculations regarding it, gauge pressure is used, but in considering the behavior of steam, such as its mean pressure, expansion, etc., *absolute pressure* is referred to. In the latter instance the pressure of the atmosphere is added to the gauge pressure.

How much moisture is ordinarily carried over in the steam from the average boiler?

It is seldom less than one or two per cent., and under poor conditions may rise higher.

How does boiler efficiency vary?

From 50 to 75 or 80 per cent. of the thermal value of the fuel.

How will steam flow through a pipe?

At gauge pressure, 15 pounds, it will flow into air at a speed of 650 feet per second, and into a vacuum at 1550 feet per second.

What is the expansion of water in becoming steam?

One cubic inch of water at 212 Fahr., becomes 1646 inches of steam, that is, at atmospheric pressure, 14.7 pounds.

If the pressure should be reduced to ten pounds how much would the boiling point be reduced?

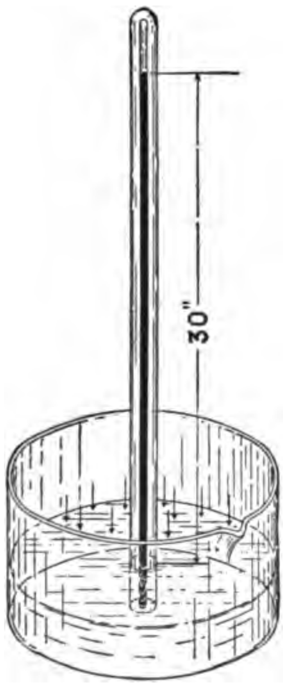
To 193°, and the expansion would be 2385 cubic inches.

What would be the pressure and expansion if it were desired to boil water at 32°?

.089 pounds pressure, and the expansion would be 208080 times the volume of the water at 39 degrees Fahr.

How does the barometer pressure vary ?

From 27 to 30 inches at the sea level, changing with the pressure of the atmosphere. As one ascends, say a high mountain, the mercury column falls about 0.1 inch for every 84 feet.



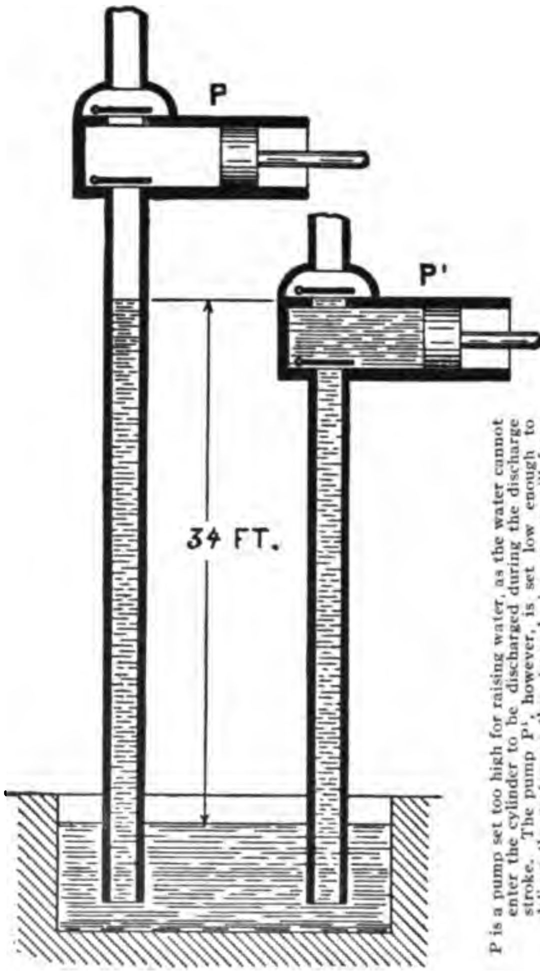
Elementary barometer, showing a column of mercury balanced by the pressure of the atmosphere.

What is the unit of pressure ?

The pressure of the atmosphere per square inch, which is equal to a column of water 34 feet, or one of mercury 30 inches; that is about 14.7 pounds.

How are lighter pressures indicated ?

By a French system, showing millimeters of mercury.



P is a pump set too high for raising water, as the water cannot enter the cylinder to be discharged during the discharge stroke. The pump P', however, is set low enough to deliver the water, as the atmospheric pressure will force it up into the cylinder.

What is saturated steam ?

Steam having a temperature due to its pressure. This is its natural state ; if any heat be added it will superheat the steam, and if any be taken away condensation will begin.

In boiler tests do varying conditions have to be allowed for ?

It is customary to figure the temperature of feed water and steam at 212° and the steam as being dry.

How is the water and steam space of a boiler divided ?

Water space two-thirds; steam space one-third.

How is the capacity of a boiler estimated ?

By the pounds of water which it is able to evaporate per hour. 34½ pounds at 212° being deemed equivalent to one horsepower; it is also equivalent to the heat required to convert 30 pounds of feed water from 100° F. into steam at 70 pounds pressure.

What should be the amount of water evaporated ?

One pound of coal should make from six to twelve pounds of steam, varying with the boiler, draft, and quality of the fuel

How large is the heating surface of a boiler ?

From 9 to 15 square feet per horse power.

What is a rough estimate of coal required per boiler horse power ?

One pound of coal will produce 8 pounds of steam, more or less, and it requires 30 pounds of steam per hour to produce one horse power.

Is it necessary to raise water to the boiling point to produce vaporization ?

At lower temperatures there is always a slow vaporization going on. This explains the formation of clouds and the drying of mud in the road.

What is the difference between absolute and gauge pressure ?

Pressure gauges in general use indicate pressure in pounds above the atmospheric pressure, consequently to this pressure 14.7 pounds should be added to make absolute pressure.

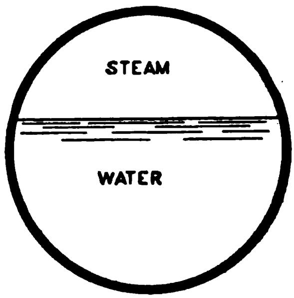


Diagram of steam and water space in a boiler

What are four notable temperatures for water ?

32° F.,	or	0° C	— the freezing point under one atmosphere.
39°.1	or	4°	— the point of maximum density.
62°	or	16°.66	— the standard temperature.
212°	or	100°	— the boiling point, under one atmosphere.

The temperature 62° F. is the temperature of water used in calculating the specific gravity of bodies, with respect to the gravity or density of water as a basis, or as unity.

What is a simple chemical test for water ?

Add a few drops of a medium strong solution of permanganate of potash to a gallon of the water. If the red color of the permanganate of potash immediately or quickly fades away and leaves the water colorless the water contains too much organic matter to be used for the manufacture of ice, and would produce an odor in the core unless special precautions are taken to prevent it.

What is the pressure of a column of water, per square inch and per square foot at 62° Fahr.?

.4335 pounds for the former and 62.352 pounds for the latter, multiplied by the height of the column in feet.

What is the pressure of a column of liquid?

The pressure exerted by a column of liquid at its bottom depends upon its height, its specific gravity, and the area of the bottom, being independent of its shape or thickness. It must be understood that by the shape of the bottom is meant the plan. If the bottom surface of a vessel varies from the horizontal the pressure will vary as the condition of the bottom.

How is water power calculated?

The weight of the water falling per minute, multiplied by the height from which it falls, divided by 33,000, will give the horse power.

How is the pressure of the atmosphere practically utilized?

In a suction pump a vacuum in the pump barrel is created by the piston; the water then flows in and mounts upward until it balances the pressure of the atmosphere; theoretically this means about 34 feet for water or 30 inches of mercury.

What are the two advantages of evaporating in a vacuum?

First, all liquids boil and evaporate at considerably lower temperatures than when under atmospheric pressure, and, second, a high temperature must be avoided with certain liquids or they will turn brown or coagulate.

What steam temperature is required in vacuum pans?

Exhaust steam is frequently used because the boiling points of most liquids are 40° C., or more, lower *in vacuo* than under atmospheric pressure.

How is the power estimated for raising water ?

In the same manner as if it were falling.

What regulates the quantity of flow ?

It depends on the area of the opening and its shape.

What law governs the flow of a liquid through an orifice ?

Its velocity depends on the height of the column of liquid above the orifice and is independent of its density.

What affects the velocity of flow of a liquid ?

The friction of the surface of the pipe, also the viscosity of the liquid.

How should boilers be laid up ?

They should be either empty or entirely full. If out of commission only for a short time the water may be made slightly alkaline by soda ash. If for a long time it is better to leave them empty and dry them out, by use of charcoal furnaces or trays of quicklime.

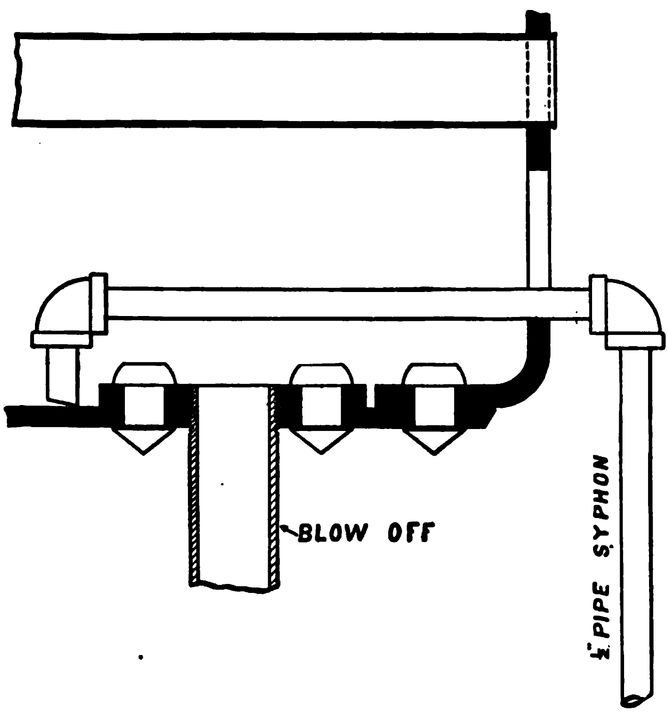
What is a good plan to pursue in laying up a boiler for a considerable length of time ?

Allow the boiler to cool down slowly, and clean it out thoroughly inside as well as outside; be sure to have all the mud and loose scale washed out, the tubes properly cleaned, and the shell swept of all soot; it is well to clean the brickwork at the same time, and remove all ashes from the grates and ash pit.

Now fill the boiler to within about a foot of the steam pipe connection, and build a fire with damp straw if possible, keep up this fire until the water has reached a temperature of about 150° to 170°.

If a sufficient quantity of straw can not be had use wood along with it sprinkled with a little tar, but do not use any coal.

When the water has reached the above temperature, fill the boiler up to the safety valve, with the main stop valve, of course, closed. Next raise the safety valve off its seat and pour as much heavy machine oil on top of the water as to overflow the



Syphon for drawing water from bottom of boiler through a handhole.

safety valve seat. Open the blow-off very slightly, so as to allow the water to leak out of the boiler at the rate of about three or four gallons a minute, and as the water level slowly

descends, pour more oil on top until there are about two to three gallons of oil floating on top of the water. Now let the fire go out, close the damper, the furnace doors and the ash pit doors, and leave the boiler until the water level shows in the gauge glass, then open the manhole. When the water has stopped running out of the blow-off, open the hand holes at the bottom, and note whether the boiler is completely drained. If the blow-off should not be at the lowest place, preventing proper drainage, syphon the remaining water out by means of a piece of bent tubing as shown on page 267, sponging out the last remains of it.

Clean the straw ashes out of the furnace and ash pit and leave everything wide open to allow the boiler to dry thoroughly. When burning damp straw in the furnace a heavy smoke is formed, largely composed of a tarry vapor, which will condense on the comparatively cool plates and cover them with a thin film of tar, preventing the moisture in the atmosphere to come in contact with the metal, and thus protecting it against rust.

The tar will find its way into the smallest crevices, where it would be hardly possible to reach with a paint brush, this is especially evident with the inside of the tubes or between the tubes of water tube boilers.

The oil floating on top of the slowly descending water will deposit itself all over the interior of the boiler, and as the water is fairly hot, it will evaporate through this film of oil, which after cooling will be thick enough to prevent the moisture in the atmosphere to come in contact with the sheets.

After the boiler is thoroughly dry a small tray of quicklime may be placed in it to absorb any excess of moisture and prevent sweating.

This mode of laying up is especially commendable for plants located at the seashore where the atmosphere is very damp. Such plants are often run only during the summer months and thus are laid up the larger part of the year.

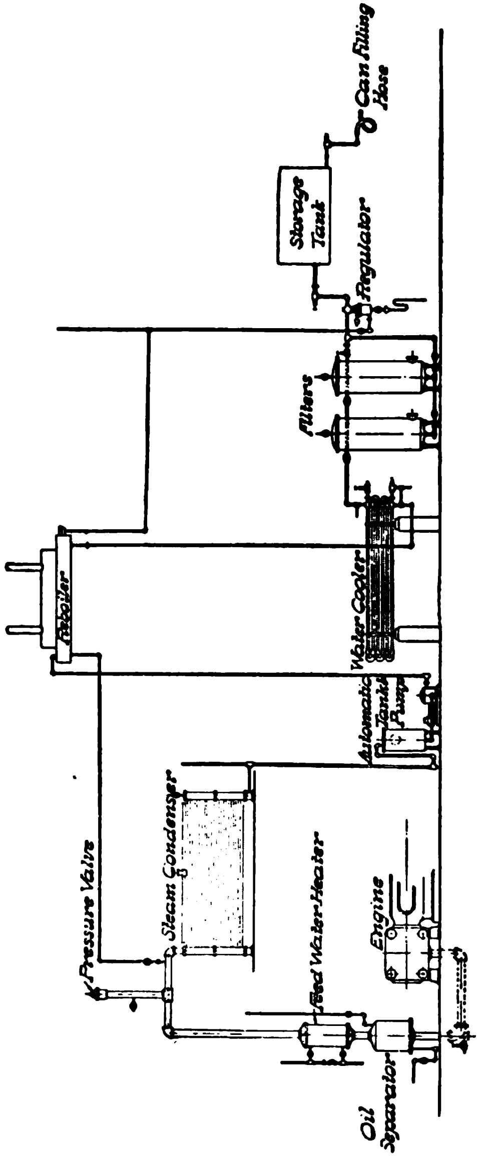


Diagram of water distilling plant.

"POINTS" RELATING TO DISTILLATION.

What becomes of the exhaust steam from the compressor of a compression plant or the generator of an absorption plant ?

It is distilled and used for ice making.

How should the distilling system be arranged ?

So that the entire system can be purged by steam.

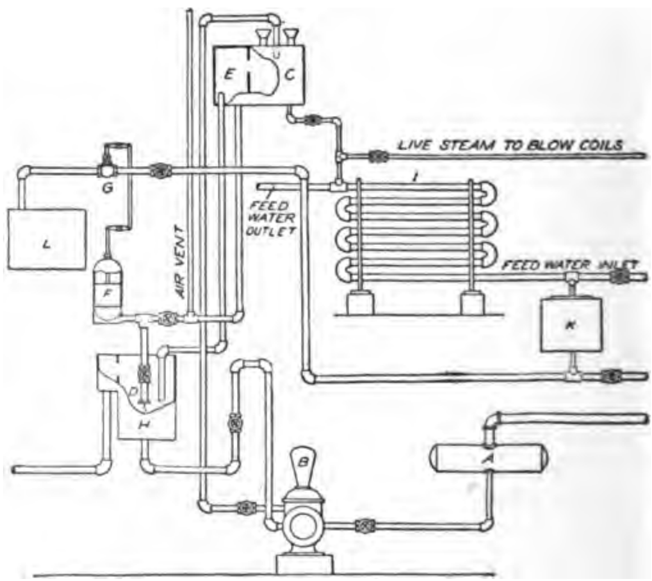


Diagram of water distilling system; see description on page 271.

Where is the exhaust steam taken first ?

It is carried through the feed water heater where it gives up a portion of its heat to the water before it reaches the boiler, thus reducing to some extent the amount of coal necessary to make steam.

What is the next step ?

The steam is now in a saturated condition, and it passes through an oil separator where it strikes against baffle plates, the impact having a tendency to separate the oil from the steam, it dropping to the bottom of the separator where it may be drawn off.

Describe in detail a diagram of a water distilling system ?

The exhaust steam enters the surface condenser, A, and when condensed the water flows from the condenser to the pump, B, which is placed below the condenser, thus the water can be pumped fairly hot into the re-boiler, C, which is set on the roof of the building. The re-boiler is made of galvanized iron with a cover on it ; two open ventilators are on top of the re-boiler to allow the foul gases to escape. A live steam coil is placed near the bottom and the water as it enters comes in contact with it, which causes the water to boil and carry the impurities toward the surface ; the air and gases are carried out through the ventilator. (See page 270.)

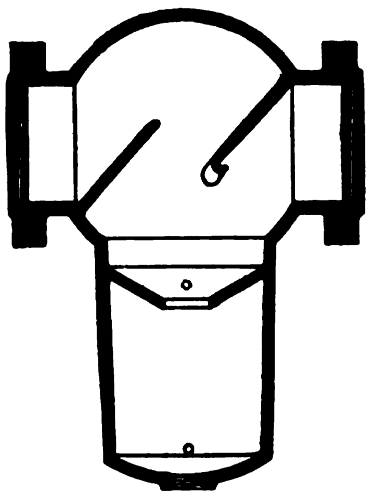
Attached to the re-boiler is a compartment, E, for skimming the oil that rises to the surface of the water.

The re-boiler is skimmed automatically by an old-time device, every twenty minutes or half hour, according to the amount of water distilled. The device used to regulate the skimming of the re-boiler works as follows : the plunger and cylinder, F, which operate the lever valve, G, are placed far enough below the re-boiler to get a head of water sufficient to raise the plunger in the cylinder. As the plunger raises, due to the pressure under it, the lever valve opens and allows the distilled water to flow out of the reboiler.

The length of time that the lever valve is open can be regulated by placing a cap, D, on the outlet pipe to the tank, H, which is used to catch the water and oil that is skimmed from the re-boiler.

Why should an oil separator be provided with baffle plates ?

Whether the oil be contained in gas or steam it is so finely divided that it will be carried along unless it is obliged to take a zigzag course by impinging against some obstruction.



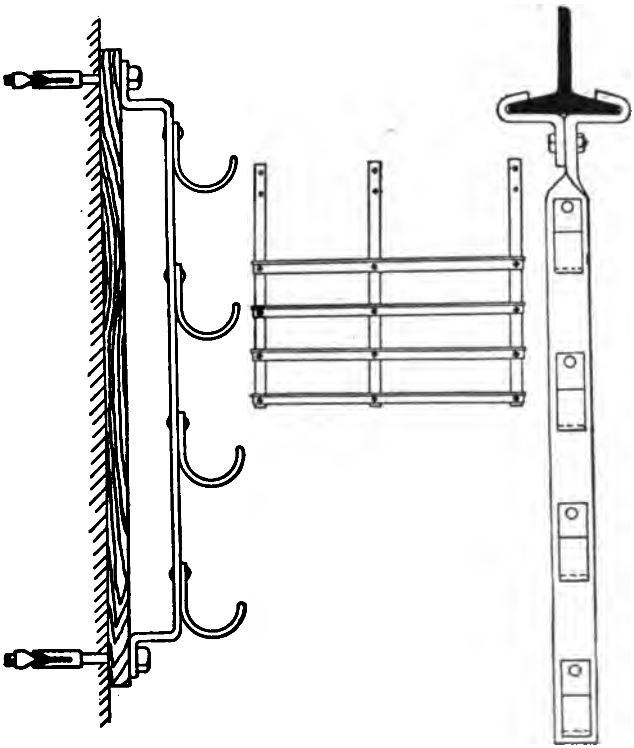
Exhaust steam oil separator. The oil is intercepted by the baffle plates and deposited in the bottom of the separator.

What fact should determine the size of the separator ?

Oil in ice gives it a peculiar gray color, and is usually due to the use of too large an amount in the engine, or to a poor separator. The former may be remedied by the use of a better grade of oil, and only such an amount as is required for the satisfactory operation of the machine. The latter difficulty may be overcome by installing a different separator. Sometimes the separator is a good one but too small for the work required of it. In determining the size of a separator always consider the velocity of the steam through it rather than the size of the exhaust pipe. The separator should be located near the engine.

How must the inlet to the separator be placed ?

So that the entering gas or steam does not strike the oil in the bottom of the separator as in that case it would be more likely to take up than to give up oil.



Various forms of pipe hangers used in refrigerating systems for expansion pipes.

Does the separator require careful attention ?

All parts of the distilled water system should be carefully watched over, and the oil separator should be kept constantly drained of the oil and dirty water; it should also be cooled so that the oil will be more viscous.

After the oil has been extracted from the steam what is the next process ?

The passing of the steam through some form of condenser is now necessary in order that the temperature may be so reduced that the steam will become water.

What forms of condensers are in common use ?

The types of steam condensers closely follow the different forms of ammonia condensers, viz.: atmospheric, submerged, double-pipe, and a special form called the "dog house," or flask condenser.

Describe the atmospheric steam condenser ?

It is like the ammonia condenser ; the steam enters at the top and as it turns to water it flows out of the bottom coils.

How are the pipe coils cooled ?

There is the same distributing trough as with the ammonia condenser but the water supply is much smaller.

Why is this ?

Because the distilled water is soon to be boiled again and it would be a waste of power to reduce the temperature of the steam more than just enough to condense it into water.

What is, therefore, the approved practice in steam condenser management ?

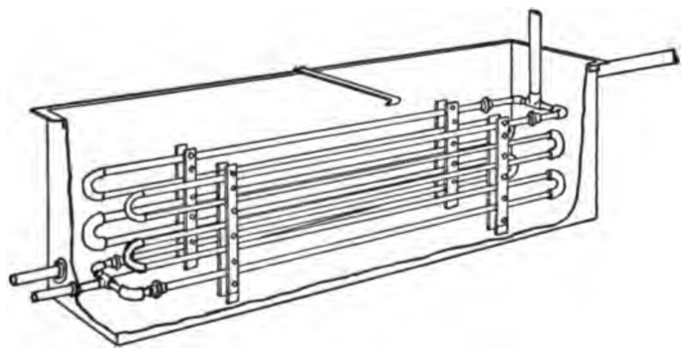
To use as little water on the steam condenser as possible, just enough to condense the water required to fill the ice cans. Keep the condenser coils scaled off clean. The hotter the distilled water comes from the condenser, the less steam it will require in the re-boiler, and the less likelihood there is of condensing, together with the steam, other free gases passing into the steam condenser along with the exhaust steam. Always allow a slight amount of exhaust steam to escape at the relief valve to carry off foul gases.

Where does the steam condenser water come from ?

It is the water which has just been used over the ammonia condenser.

Should care be taken to keep the condenser coils clean ?

It is necessary for their efficient working that they be kept clean and free from scale.



Submerged steam condenser: the steam passes through the pipes while the water enters the tank at the bottom and leaves at the top.

How does the piping of the distilling system differ from that of the ammonia cycle ?

In the former system, as there is no ammonia brought in contact with the pipes, they may be galvanized whenever their alternate exposure to water and air would cause them to rust.

Describe the submerged condenser ?

It is an open galvanized tank containing steam coils; as it does not require large space it may be placed in any convenient place.

Under what circumstances is it used ?

It can be used wherever on account of the mineral matter in the water it is not practicable to use a double pipe one.

It can also be placed in a room where the vapor from an atmospheric one would be objectionable.

How is the submerged condenser operated ?

On the counter current principle, the steam entering at the top and the condensed water passing out at the bottom.

The cooling water comes in at the bottom and flows out a little above the upper pipe.

How should the pressure in the condenser be regulated ?

The pressure in the steam condensers should remain as nearly constant as possible. They should never be allowed to blow violently, as this carries over whatever oily sediment may have settled in them.

Under what conditions is the double pipe condenser used ?

Where the quality of water is such that a double-pipe condenser is used for the ammonia the same pattern is frequently employed for the distilled water.

How is it operated ?

The exhaust steam enters the headers at one end and passes through the space between the inner and outer pipes, thus being subjected to the action of the cooling water from the inside pipe, and a large amount of heat being radiated into the atmosphere through the outer one.

Why is its use desirable ?

It is compact, easy of access, and may be quickly cleaned and repaired.

How may the double pipe condenser be cleaned ?

There is usually provision for attaching a steam connection to each coil for blowing-out purposes.

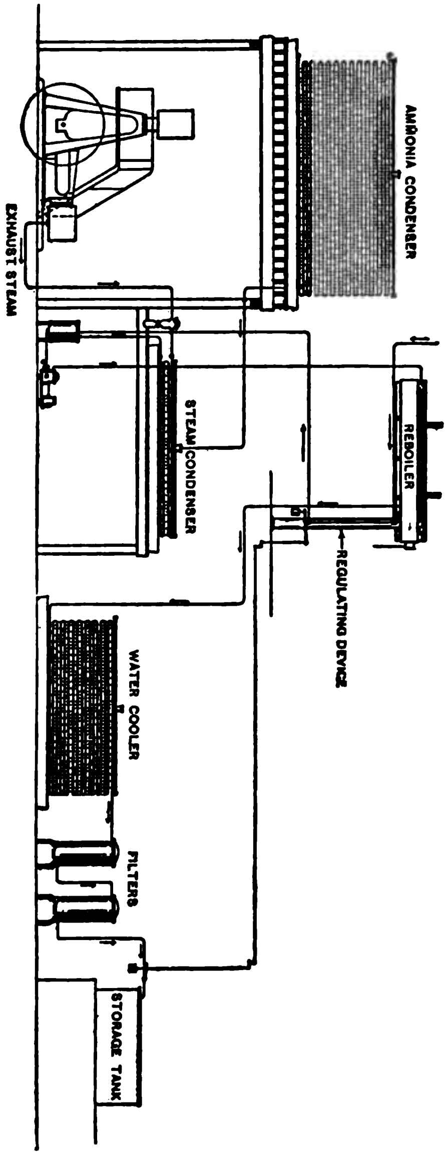
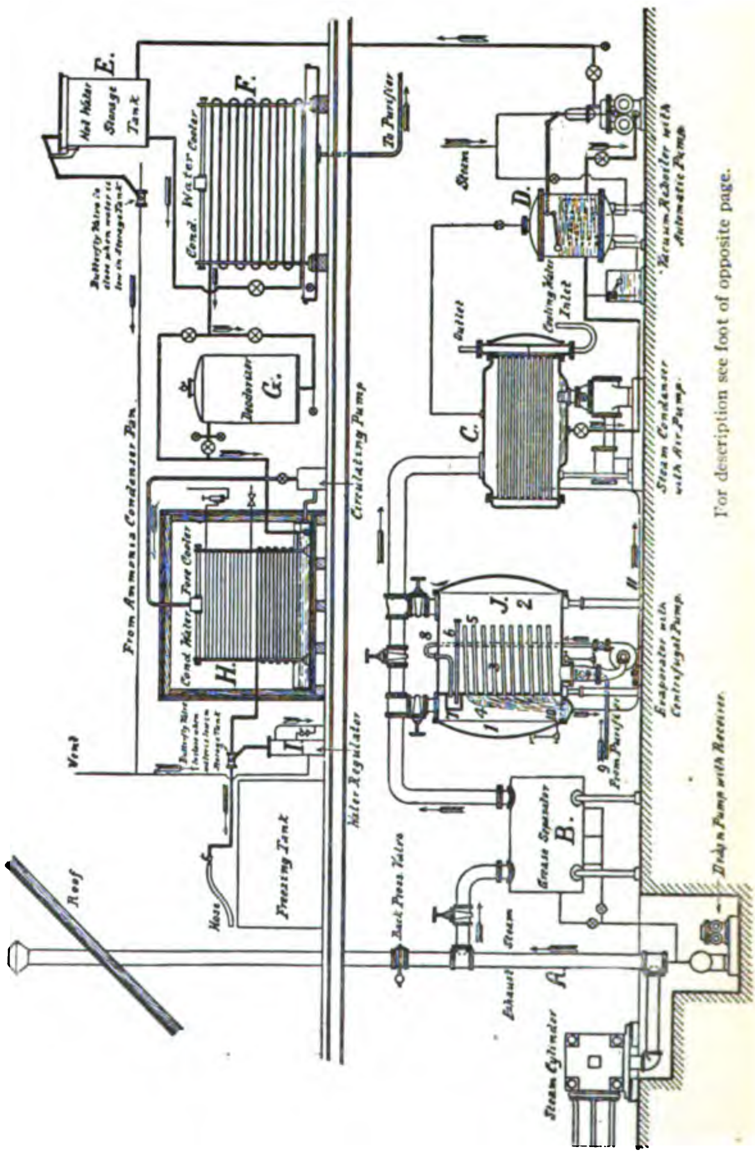


Diagram showing Eclipse distilling plant.



For description see foot of opposite page.

Describe the "dog-house," or flask condenser.

This condenser is built of galvanized sheet iron, and the top and bottom of the shell are a continuation of the sides, while the shape of the apparatus offers no difficult angles or corners in which scale might lodge.

Scale accumulates on the flat sides, and upon reaching a certain thickness, usually falls off in large slabs, due to the vibration or "breathing" of the condenser. It is not necessary to interrupt the operation of the condenser to clean it.

Inspection of the interior is provided for by a manhole placed at one end of the condenser. The entire inner side of the condenser is strengthened by a series of angle iron braces extending lengthwise of the condenser and securely fastened to the shell.

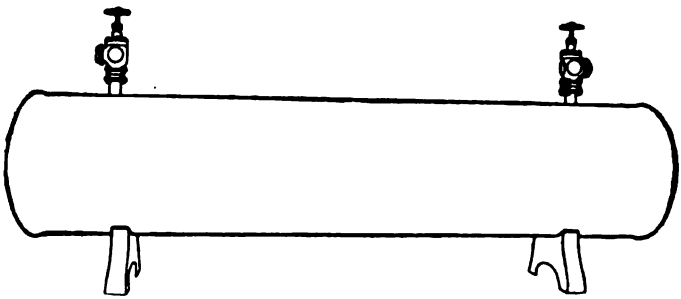
How is the distilled water further treated for the removal of oil and impurities ?

After leaving the condenser it is passed through a skimmer.

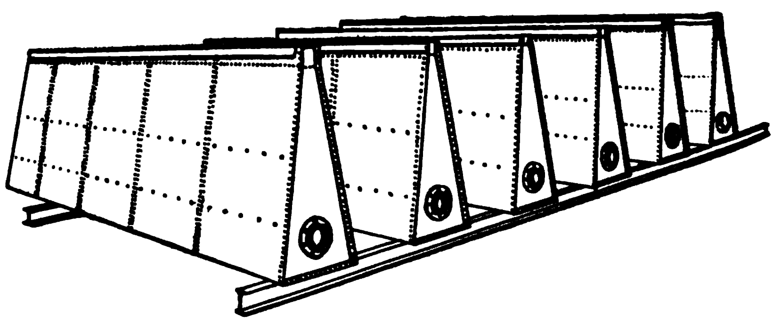
(See opposite page).

Diagram of vacuum distilling system. The steam from the exhaust pipe A passes through the grease separator B, but on its way to the condenser C the pipe is supplied with a by-pass by means of which the steam can be compelled to pass through evaporator J. From the condenser the water flows into the vacuum reboiler D, from where it is taken by an automatically controlled pump and discharged into the hot water storage tank E. From the storage tank the water passes through the water cooler F into the deodorizer G, and hence into the condensed water forecooler H. The flow of the water from the forecooler to the freezing tank is regulated by the regulator I. This regulator is controlled by the water level in the storage tank. A butterfly valve in the pipe to the freezing tank is held open by water pressure upon a piston in the cylinder I, but when the water level in the storage tank drops, a valve in the pipe supplying the hydraulic cylinder is closed by the dropping of a float, and as the water in the cylinder I drains away, the filling pipe valve is closed by the descending piston. The pipe leading through the deodorizer is supplied with a by-pass to be used while cleaning out the deodorizer.

The evaporator J consists of a shell 2 supplied with a removable head 1. The exhaust steam enters the chamber 4 and is passed over a number of pans 3 into the chamber 5. A centrifugal pump circulates water over these pans, the water is discharged through pipe 8 into the header 7, and from there passes through a number of sprinkling pipes 6, over the pans. The water running off the pans is collected at 10 and again circulated by the pump. The exhaust steam passing through the evaporator takes up a large amount of vapor of the water, being heated in a vacuum, and carries this vapor over into the condenser.



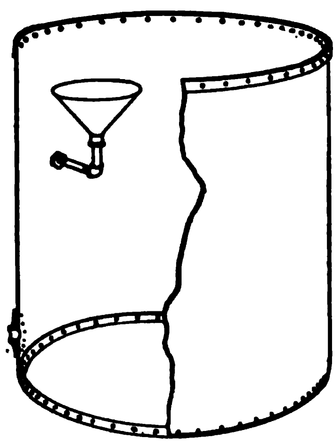
Ammonia receiver with heads welded into shell by oxy-acetylene process, making the receiver absolutely seamless.



Battery of "dog house" condensers for machine of 75 ton capacity.

Describe the oil skimmer.

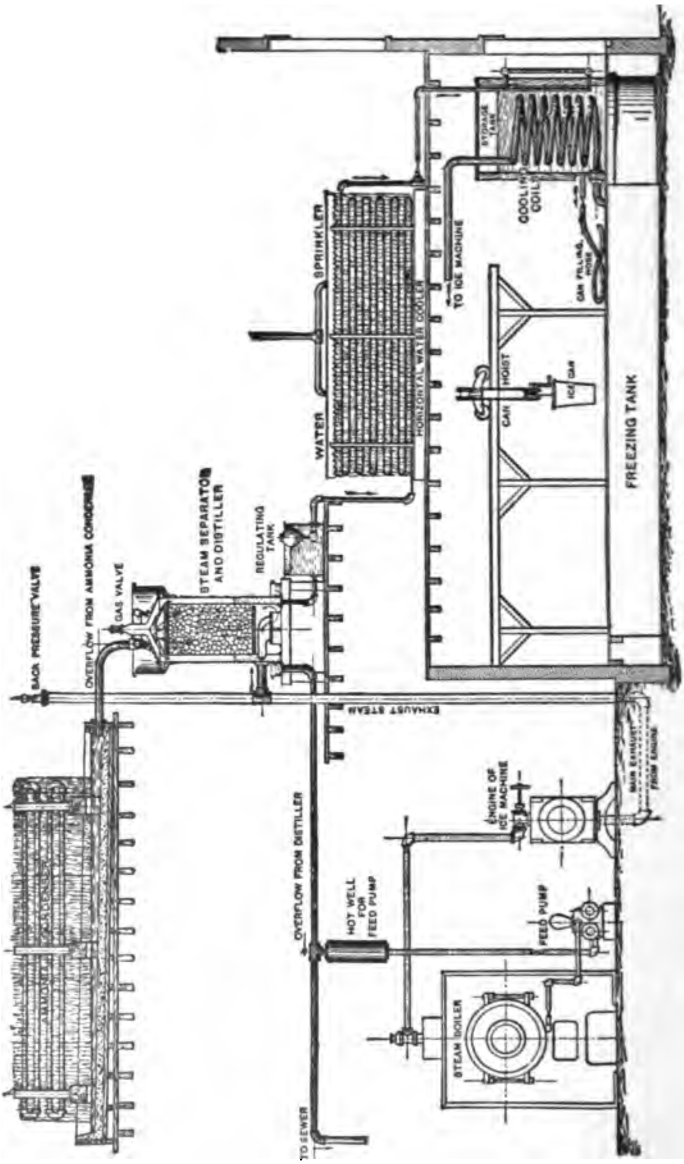
An oil skimmer is always included in a first-class filtering and distilling apparatus. They are made cylindrical in shape. They are arranged so that the oil or grease which is abstracted from the water floats on the top and is caught in an oil trap and carried off to the sewer or any other convenient place, while the clear water is drawn off from the bottom and passes on to the reboiler. They are made of heavy galvanized iron and are reinforced at the top with a heavy galvanized iron band. All joints are riveted and soldered, and all of the fittings and connections which come in contact with the water are galvanized.



Skimming tank with funnel surface blow for removing oil or other light scum from the distilled water.

For what should the skimmer be carefully watched?

The oil trap should overflow or be made to flush at regular intervals.



Eclipse distilling system showing steam plant and freezing tank.

What is the next stage in the treatment of the distilled water?

It has now reached the re-boiling process.

Describe the work of the re-boiler.

It is a very important part of a distilled water plant for it is depended upon to work all the air and foreign gases out of the water, and to extract any minute particles of oil or grease which may still remain in it.

Describe the re-boiler.

It is frequently cylindrical in shape with a live steam coil placed near the bottom.

The heat from this coil causes the water to boil, thus forcing the grease or other impurities toward the surface, where an arranged overflow carries them into a trap, while the air and gases are taken off in a special flue.

Re-boilers of this shape are made of heavy galvanized iron and properly re-enforced at top and bottom.

What kind of a coil should be used?

Use a closed coil in the re-boiler in preference to a perforated coil. A perforated coil often gives the appearance of boiling to the water in the tank when the temperature is still below 212 degrees. Keep the re-boiling tank up to 212 degrees, and run the waste steam from the re-boiling coil into the steam condenser.

What is a more modern form of the re-boiler?

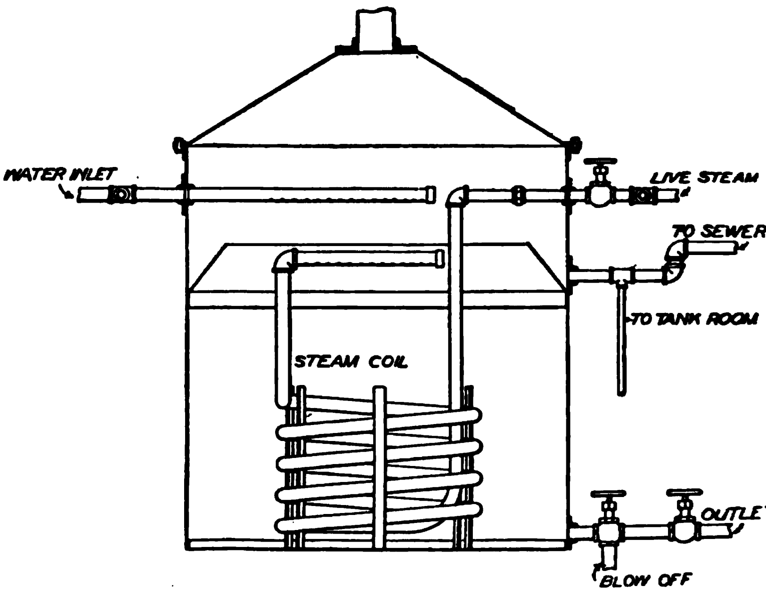
A flat rectangular tank, the coils extending its full length. Water is admitted at the rear end and passed over the full length of the steam coils before entering the skimming and discharging chamber.

What takes place in this chamber?

The oil and impurities floating on the surface of the water are skimmed off by means of V-shaped openings in the end of the tank.

Is this form of re-boiler more efficient than the cylindrical type?

A long, flat reboiler will more thoroughly reboil every part of the water than the old round tank reboiler, and it will allow the gases to escape without coming in contact with, and being absorbed by, the incoming water. Again, with a round tank reboiler it is almost impossible to tell whether the water leaving it has been properly re-boiled or not.



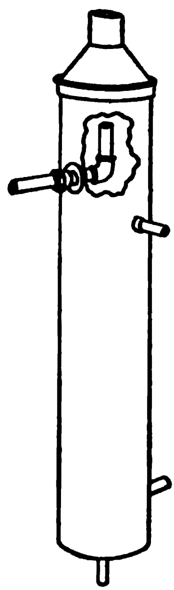
Apparatus for reboiling condensed water for ice-making purposes.

Is there considerable difference in water as regards re-boiling?

Some waters hardly need re-boiling at all. This explains why some designs of apparatus produce good ice in one locality, whereas they will not in others.

Should care be taken in re-boiling?

Re-boiling the water too hard causes too much agitation, retarding the separation of the oil and other impurities from the water, and allowing too much of the water to pass off in vapor.



Skimming tank with plain pipe surface blow. The tank is made deep and narrow, thus the scum and oil is not spread out over a wide surface, and collects near the flow.

Why is the re-boiler an important adjunct?

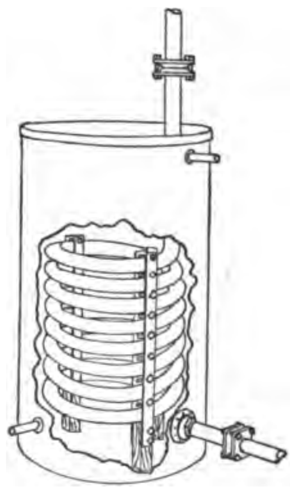
Organic matter, which is ever present in the water, passes from the boiler with the steam, and is re-absorbed when the steam is condensed, and the duties of the re-boiler are to expel all the volatile matter, including the organic matter of the cylinder oil. The mineral particles of the cylinder oil are removed by skimming and filtering.

Why must the re-boiler be closely watched ?

Water is a poor conductor of heat, and one part of a re-boiler may be boiling while other parts are comparatively cool.

What is now the course of the water ?

It passes from the re-boiler, through pipe coolers (or flat coolers), filters and storage tank (the suction pipe from the expansion coils to the compressor passes through it), to the can fillers. The water on its way down should flow by gravity, the pipes being perfectly tight, and its temperature lowered to as near the freezing point as possible, making just that much less work to be done in the freezing tank.



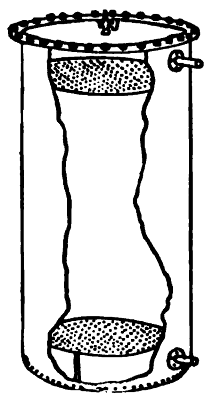
Storage tank for distilled water with expansion coil for keeping the water at a low temperature.

What is now the temperature of the distilled water in the storage tank ?

If the water is cooled down to 40 degrees F., or below, before it enters the freezing tank, little trouble will be experienced in making clear ice. This applies to plants making ice from raw water also.

Does the cooling coil require special care ?

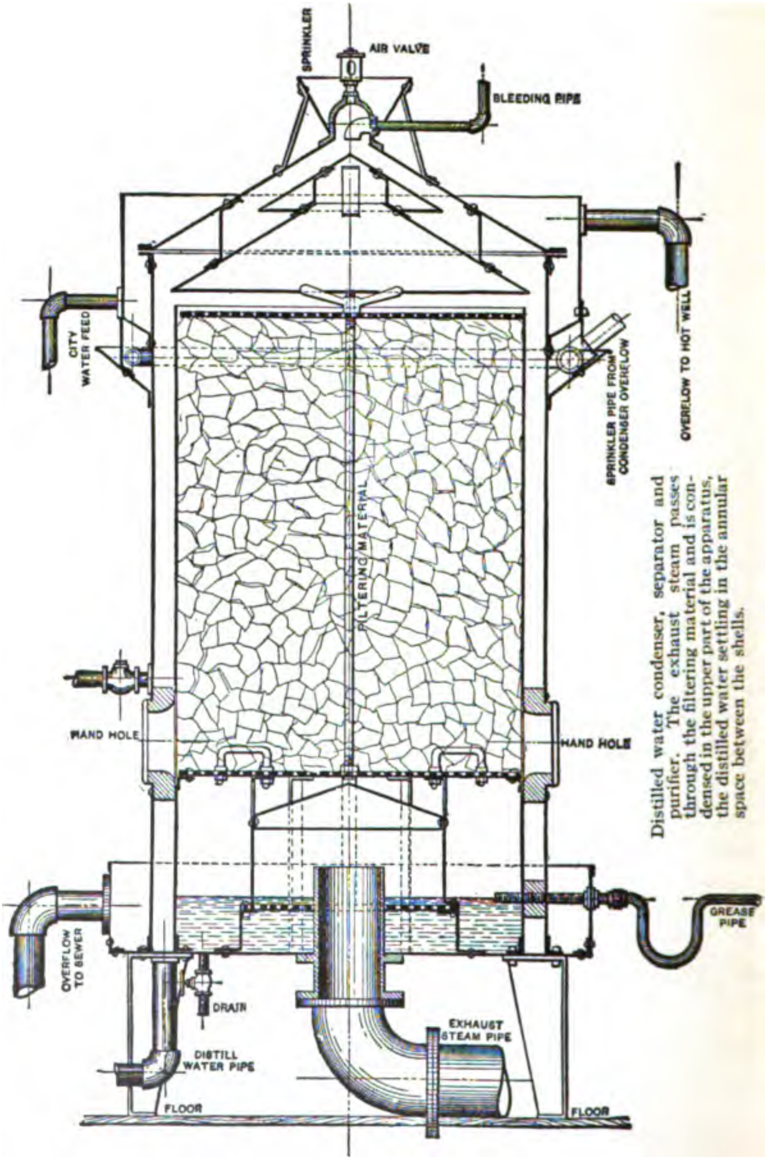
Blow out the cooling coil regularly. It may be once a day, or as often as required by the nature of the water handled, but have some regular time to attend to it. The cooling coil is a most important part of the plant and should be supplied with a liberal amount of the coldest water available. Every unit of heat extracted from the water while passing through the cooling coil is one less for the ammonia to handle.



Filtering tank for distilled water. The space between the screens is filled with charcoal, the water entering at the bottom and leaving at the top. The cock in the cover is for removing air.

Should the water be kept in motion in the storage tank ?

The use of agitators in storage tanks has not been found to be good practice, for it keeps the sediment stirred up which passes into the ice cans and lowers the quality of ice manufactured.



Distilled water condenser, separator and purifier. The exhaust steam passes through the filtering material and is condensed in the upper part of the apparatus, the distilled water settling in the annular space between the shells.

Is great care necessary all through the distilling process ?

In plants where distilled water is used, the purification process should begin with the feed water before it goes into the boilers.

This water should be thoroughly filtered, and where it contains any quantity of foreign matter, it should be heated up in an open heater, so arranged that a small quantity of the steam is allowed to escape all the time. This will carry away much of the objectionable gases.

Care should be taken to keep the distilled water apparatus full of water, so as to prevent air from being admitted to it and in this way make white ice. In plants where raw water is used the water should be well filtered and the tanks kept clean. The entire system, including the filters, should be blown out occasionally.

What is a common form of filter used ?

A very necessary part of the equipment of an ice plant is the deodorizer or charcoal filter for extracting any impurities or odors from the distilled water on its way to the ice cans, and it generally forms the last step in the process of filtering and distilling the water to be used for ice making. These filters, while designed primarily for use in ice plants, are well adapted for general use. They are cylindrical in shape. The seams and heads are well riveted and caulked, making them absolutely tight. They are provided with a man-hole on top and one or two hand-holes on the bottom, according to size. The deodorizer is filled with charcoal, and the connections made in such a manner that the water will enter the bottom, pass up through the charcoal and out at the top.

Do charcoal filters require frequent cleaning ?

The charcoal filters should be cleaned often, because they are actually becoming fouler, and after a while will add to the impurities contained in the water instead of removing them.

Are coke filters used in the distilling process and for what purposes?

They were formerly used for taking out the oil from the steam but are now largely superseded by the oil separator.

Describe one of the forms of coke filter.

These coke filters are designed for removing the oil from the exhaust steam on its way to the steam condenser, and are connected up so that the exhaust steam enters at the lower inlet, and rising, passes through a large mass of coke, where the oil is extracted from the steam and drops down to the bottom of the filter, from whence it goes to the sewer or other convenient place. The steam, after being cleansed of oil, passes out of the upper inlet and goes to the steam condenser. They are made cylindrical in shape, of heavy galvanized iron, and the seams are riveted and soldered, which insures perfectly tight joints. They are also provided with a series of galvanized wire screens, which stretch across the inside diameter of the filter and hold the coke in its proper place.

Why is the distilled water liable to contain oxide of iron ?

Water, as a general rule, contains carbonic acid, and as the water leaves the boiler in the form of steam, the acid passes off as a gas, and when the exhaust steam is condensed, the acid having an affinity for iron, forms oxide of iron, which is insoluble and is held in suspension by the water the same as earthy matter or other material, and can be removed readily by a good clean filter.

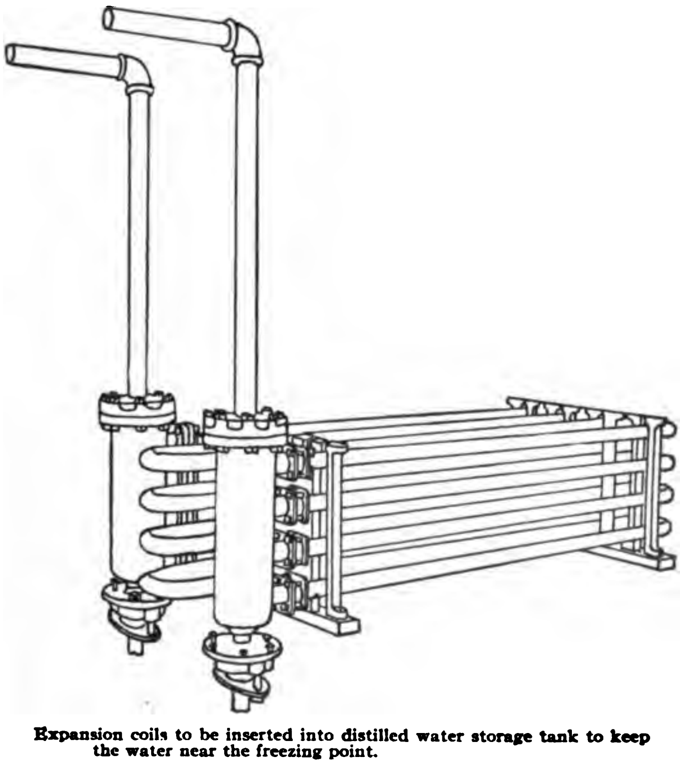
Why is the final filtering of the distilled water very important ?

The appearance of the ice is more dependent on the filter equipment than upon any other part of the plant. A filter like the International will arrest oil, dust or other foreign matter, and prevent red core or other discoloration of the ice.

Describe the International filter ?

The filter body consists of two iron shells which are hinged together and clamped around the edge by means of hand bolts.

The inlet is in the lower shell, the outlet in the upper one, thus making the filtration upward, so that the heavy particles in the water tend to fall away from the filter medium instead of clogging it, as when the filtration is downward.



Expansion coils to be inserted into distilled water storage tank to keep the water near the freezing point.

Where should it be placed ?

Between the storage tank and filling hose ; it being the last stage before filling the cans.

How is the filtration accomplished ?

The filter discs are made of a cloth of peculiar texture, which will remove rust congealed oil, etc., from distilled water. When the rust or other foreign matter in the water is in a very finely divided state, or where natural water is used, filter discs of pure compressed cotton fibre are used in addition to the usual cloths.

The filter discs present a perfectly uniform filtering surface, so that absolutely all suspended matter in the water is arrested.

The filtering is accomplished by these filter discs, locked all around the edge between the two filter shells. Owing to this construction, all the water must pass through the filter discs, there being absolutely no way for it to pass around them.

Are lead or rubber gaskets used ?

As there are no loose parts to get lost, no rubber or leather gaskets are used. This is an important feature, as these require much time in adjusting and replacing.

How is this filter made ready for use ?

Open the filter and place two cloth discs on the lower screen. If the water contains much rust or fine particles place one or two of the paper fiber discs between the cloths. Then close the filter and lock tight. Turn on the water supply slowly, so as to allow the air to escape through the air cock on top.

What is done when the filter becomes clogged ?

When the flow of water becomes slow close the inlet of the filter, open the air cock on top, unlock the filter, raise the top, remove the paper discs and replace with fresh ones.

The cloth discs may be washed with soap, and rinsed, and then can be used again.

The paper discs, however, must be thrown away after once using.

Where should this filter be placed ?

Between the storage tank and the freezing cans. If possible the filling hose should be connected with the outlet of the filter, but if this is not practicable all pipes through which the filtered water passes should be galvanized.

How long does it take to make this change ?

The filter can be opened, the discs changed, the filter closed and made ready for use again in two minutes. There is no loss of distilled water and no air is allowed to enter the system.

Is any pump required ?

No pump should be used in connection with the filter, unless relief valve and pressure gauge be attached between the pump and the filter, so that no more than 50 lbs. pressure be brought to bear upon the filter.

How should the filter be placed for gravity or city water supply ?

When gravity pressure is used the unfiltered water should be at an elevation of six feet or more above the filter. When city pressure is used, the filter should be connected directly with the water supply. When the regular or fire pressure exceeds 50 lbs., a pressure regulating valve set at 50 lbs., should be placed on the water supply.

What is the advantage of this filter from a sanitary standpoint ?

The compressed cotton fibre discs are discarded when clogged and replaced with fresh ones, thus assuring absolute cleanliness at all times. Nothing less than complete and thorough sterilization or the entire renewal of the filter medium should be accepted by the user. Where the filter medium is only washed or scraped and used continuously as in the case of stone and porcelain filters, the bacteria find a convenient breeding place in the filter medium and multiply with remarkable rapidity, growing through the pores of even the finest stone or porcelain.

What is a cooling tower and why used?

Where water is scarce or expensive, so that it is desirable to cool the water after it leaves the condenser in order that it may be used over and over, some apparatus is needed to expose the water to the action of the atmosphere, and the cooling tower has been devised for that purpose.

In its various forms it is merely a skeleton framework or tower so constructed that the water, when pumped to the top and then allowed to fall, spreads out in thin sheets.

How are they divided into distinct types?

The variability of cooling towers with atmospheric conditions has led to the development of two types. The amount of cooling produced depends primarily upon the condition with respect to humidity of the air and, secondly, upon its temperature. The capacity of the tower depends upon these factors and upon the amount of air brought in contact with the water per unit of time. This latter feature is the main determining factor in the development of the two types. These are known respectively as the closed and open types of tower.

Where is the open type mainly used?

In plants where the cost is a matter of great importance, and the possible isolation of the tower a simple problem, the open type has been developed. In the majority of small refrigerating and ice-manufacturing plants where the question of cost is a matter of prime consideration, the open type is almost invariably installed, and is usually placed on the roof.

How much does the cooling tower reduce the temperature of the water?

The heat is absorbed by contact with the air, and also by the evaporation of a small percentage of the water, so that the temperature of the water may be reduced from five to fifteen degrees below the temperature of the air.

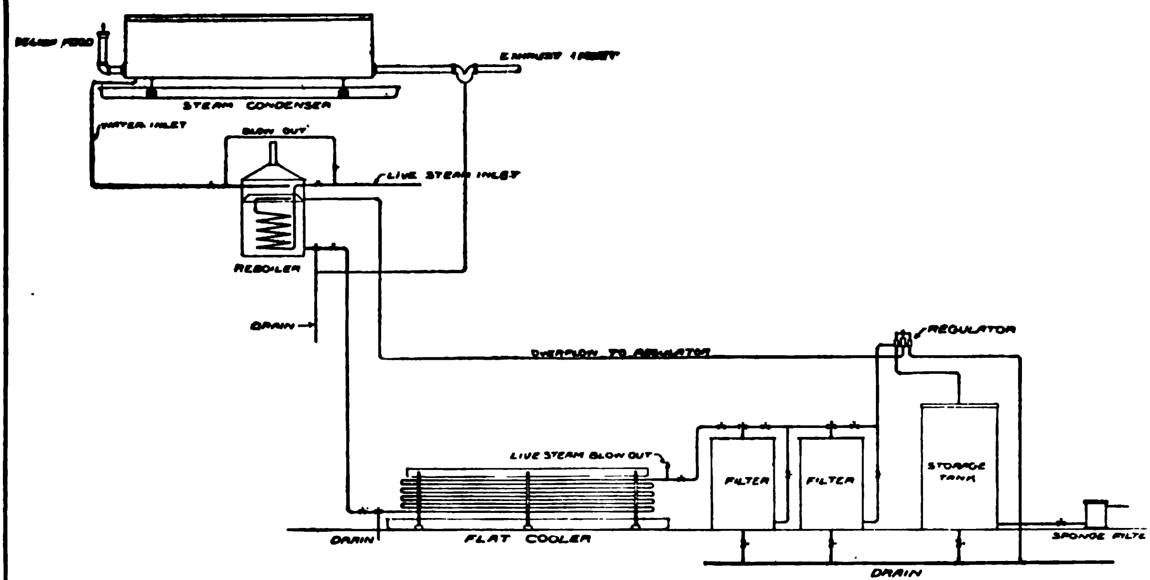
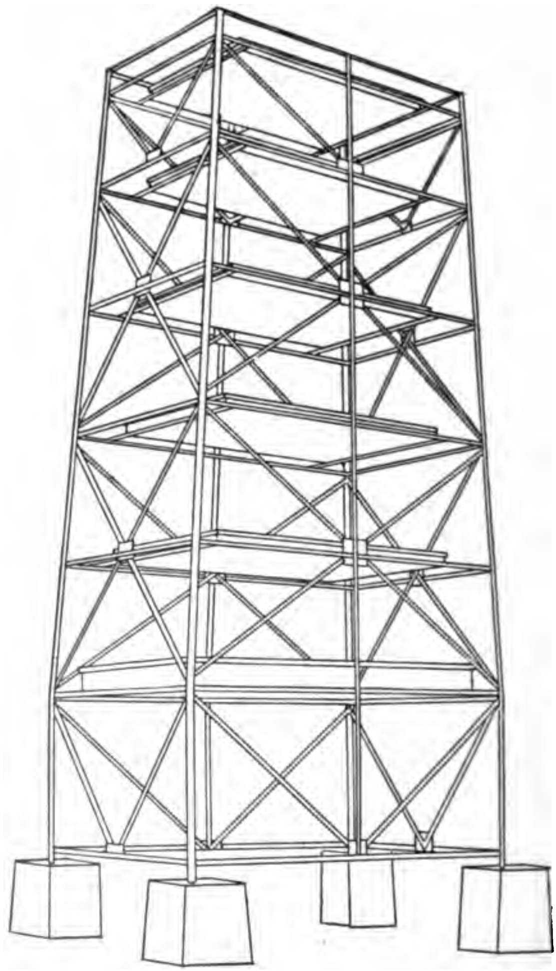


Diagram of water distilling system, showing the course of the water from the exhaust pipe to the storage tank.



Open cooling tower. The water is discharged into the top pan and after passing through all the various pans returns back to the condenser.

What is the construction of the open type ?

The chief open types consist practically of drip pans installed at regular intervals, allowing free access of the air between them, and possessing holes in these at intervals for the equal distribution of the water. Shavings, boards, mineral wool, tile and even slate, have been used with greater or less success in this type and in the closed type as well. The question is largely one of expense installation and consideration of the deterioration factor. Almost any device for satisfactory distribution and separation of the water, with adequate retardation, is satisfactory for the purpose. Such a tower is open at the sides and depends upon the natural air circulation in the atmosphere. Its efficiency varies with the velocity of the wind, its humidity and temperature, and also upon the design of the tower for separation and retardation. The deterioration factor in this type is quite large, since the destructive effect of air and water under these conditions is considerable.

What are average dimensions for a cooling tower ?

A cooling tower for a fifty-ton plant would be approximately 12 feet wide by 6 feet long, floor measure, and 24 feet high.

The air supplied by two fan blowers about 8 feet in diameter would be sufficient, and these fans would consume about eight horse power.

Why are they variable in actual working ?

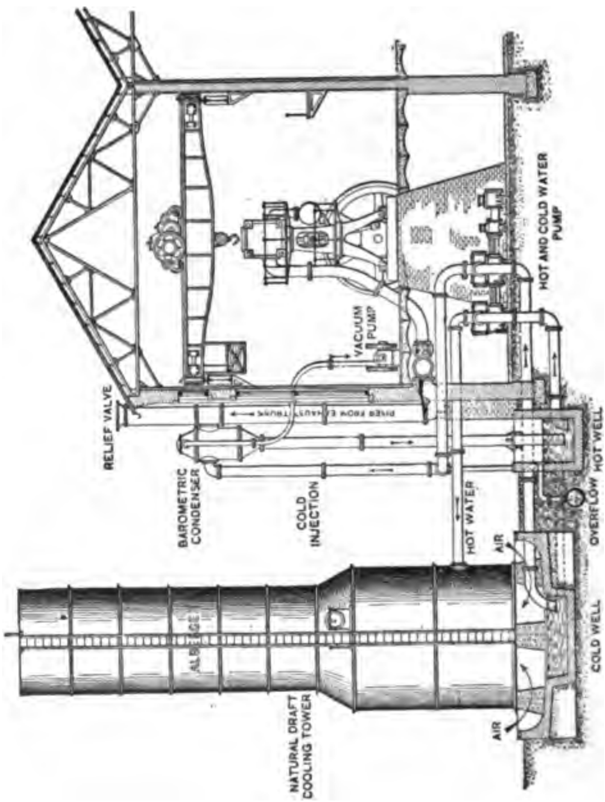
Cooling towers are quite variable in their action being dependent upon the condition of the atmosphere in regard to humidity, since the actual loss of heat by conduction from the water to the air is quite small under any circumstances.

What is the theory of its operation ?

Air possesses the property of absorbing large quantities of water vapor from a water surface with which it is brought in contact.

How many degrees can water be cooled by mechanical draft?

The temperature depends upon the condition of the atmosphere or its holding water in saturation, which varies all the way from dry air to dew point.



Natural draft cooling tower connected to steam plant with barometric condenser.

At times when the percentage of humidity is very small the temperature of the water can be reduced some sixteen or twenty-two degrees.

What is the advantage of these towers ?

The cooling effect under ordinary circumstances is very large, since every pound of water evaporated by this means is accompanied by the absorption of heat from the remaining water, equivalent to the latent heat of vaporization of the water changed into vapor.

What is the range of the efficiency of the tower as regards reduction of temperature ?

Very seldom in summer can the water be cooled much below 75 degrees Fahrenheit. The higher the temperature of the initial water, however, the more efficient is the tower in its operation.

Condenser water from steam condensers is furnished at a temperature ranging from 165 degrees down to 80 degrees Fahrenheit, and their operation under these circumstances is very efficient. Refrigerating plants have a range of temperature depending simply upon the pressure maintained in the condenser and seldom rises above 120 degrees Fahrenheit for initial temperature in the cooling tower. The evaporation of the water in the cooling tower must, of course, be re-supplied, and this represents a certain loss. In refrigerating plants the loss of the water is from 5 to 15 per cent. for each circulation.

Is a cooling tower preferable to a deep well pump ?

Which is the cheaper can be easily calculated. The cost of pumping may be the same with additional wells, pond or cooling tower, and it is in most cases less for the latter because more efficient pumps can be used, such as centrifugal pumps.

Deep wells with expensive pumps or air compressors will cost considerably more than a good fanless cooling tower, and surface wells may cost as much or a little less in the first cost. But no well will give as big an increase as a cooling tower, and those plants which have to fill ice houses during the colder season will obtain colder water from a cooling tower than from

a well. Where deep wells furnish pretty warm water which is at the same time very hard, cooling towers have been resorted to before the water could be used at all, and have successfully eliminated much of the mineral matter contained in the water.

Would there be an advantage in using deep well water for ice making?

There are many cases where the use of an air lift instead of a pump is attended with incidental advantages, as when the water is to be used for cooling or condensing purposes. The refrigerant effect of the expanding air being sufficient to lower the temperature of the entire body of water, in some cases as much as twenty degrees.

What is the cost of pumping water?

Water can be pumped by a properly designed and operated pumping plant, in quantities from one to one and one-half million gallons daily, for a distance of 2,000 feet and elevation of 90 feet, for 8 mills per 1,000 gallons. This is operating expense in connection with the refrigerating plant, and does not include maintenance or interest on the amount invested.

How does the water supply largely determine the type of tower?

The efficiency of a cooling tower, of course, depends primarily upon the cost, availability, and character of the water supply. It must not be pumped too great a distance, or too great a height. Every individual plant presents special conditions for consideration in regard to its availability, and its efficiency is practically dependent upon these conditions.

What is a serious objection to the open tower?

When high winds exist the water cannot be restrained within the confines of the cooling tower, and a fine spray covers all the surrounding objects. This may lead to a lawsuit from an adjoining property owner.

Describe the closed type of tower?

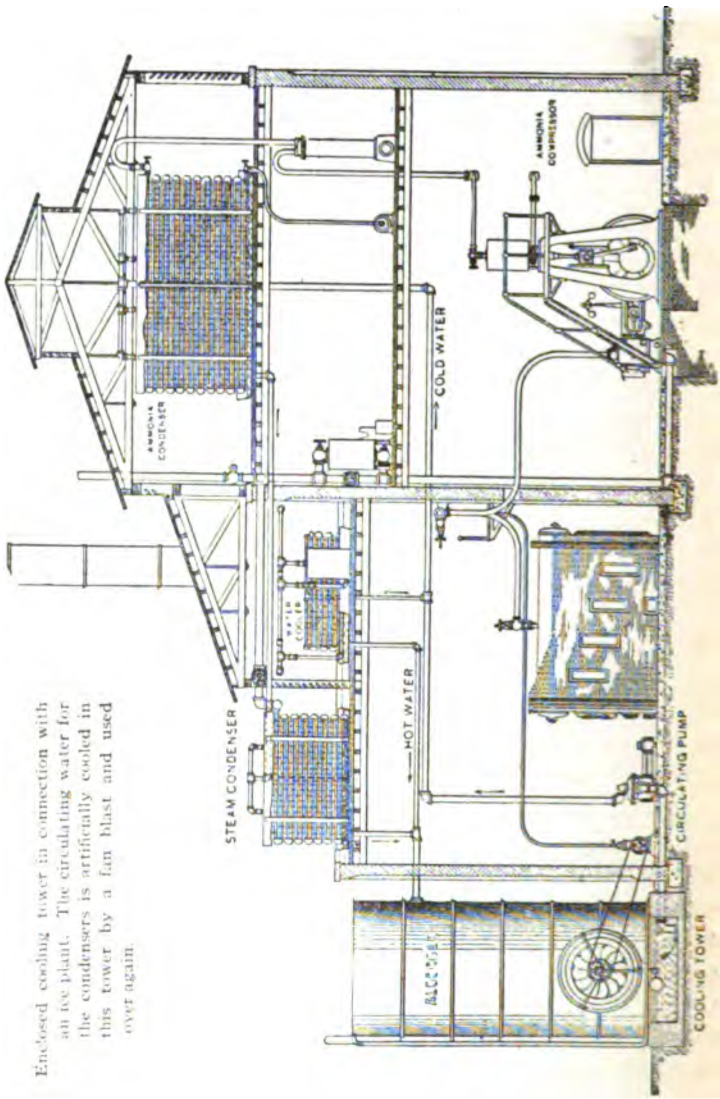
It is practically identical with the open type in construction, with one important modification. The walls of the tower are inclosed and air is supplied at the bottom and forced upward throughout the tower by means of a fan. The air supply under these circumstances can be varied by mechanical means and the resulting cooling effect made practically independent of temperature and humidity variations of the outside atmosphere. The operation of the tower is further independent of the existence of winds for its efficient operation.

Is the closed cooling tower always the most desirable?

When considering cooling towers there may be no need for those with fans, requiring an outlay of much money for the installation and a continuous expense for running and repairs, except in cases where a larger floor space is not available. In the majority of plants there is always plenty of space in the yard, or on top of a roof, or over the condensers, for a sufficiently large cooling tower without a fan, which, if properly constructed, gives identically the same results as those with fans, and which can be installed at a cost low enough to be in reach of all, and which does not cost one single penny to be operated, except the pumping of the water, which expense is the same for both types. The amount of water used is an important item about an ice plant unless there is an unlimited supply. If water is purchased it should be passed over a cooling tower, and used again and again. The cooling tower will pay for itself in a short time in the amount of water saved.

Where is the closed type favored?

In installations where reliability is a matter of prime importance and cost of installation a matter of minor significance, the closed type is invariably chosen. The majority of large power plants use the closed type.



Enclosed cooling tower in connection with an ice plant. The circulating water for the condensers is artificially cooled in this tower by a fan blast and used over again.

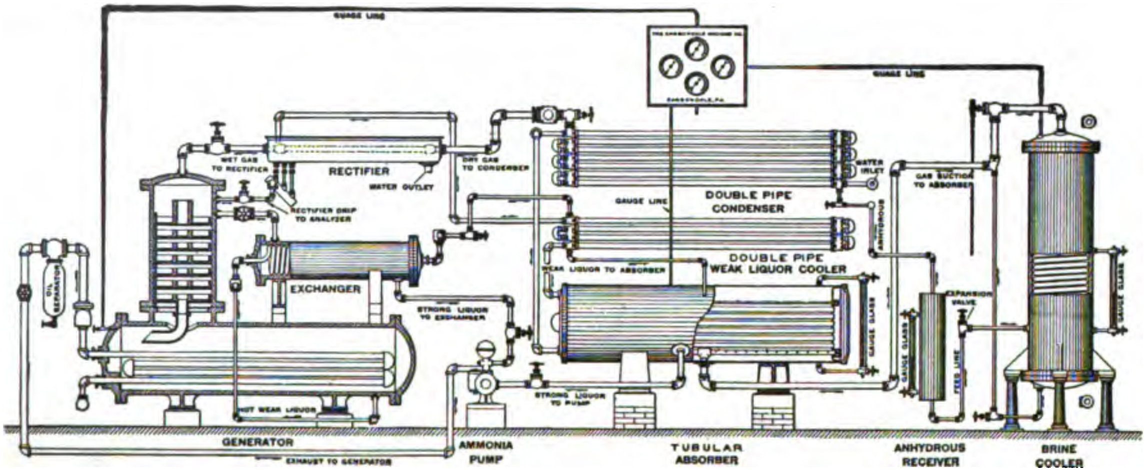
Is the quality of the water important in ice making?

When river water is to be used for the manufacture of ice, it will always pay to put in a feed water heater and purifier even if the water is low in scale-forming solids. In nearly every case river water contains more or less sewage matter which produces free acidity in the boiler and causes corrosion. If an examination of the water is made, and a feed water purifier is used, this can be properly and completely neutralized in the purifier by the use of soda ash, or any other suitable alkali, and the corrosion prevented.

It is very much better to effect the purification before the water enters the boiler if the water is very bad, as it is not well to introduce the heavy sludge that would be formed, directly into the boiler.

There seems to be a general impression that if water is treated in a water softening apparatus it would be suitable for the manufacture of can ice without distillation or reboiling. This is not so at all, as the water contains as much occluded air as before treatment, which would cause the ice to be opaque and the purified water, if the lime and soda treatment is used, would contain a fairly high content of sulphate of sodium, as a product of the chemical reaction which takes place during the purification, and this salt, which comes out of solution at low temperatures, would give the ice a dirty gray appearance and retard the process of freezing.

For the manufacture of can ice the water should be low in scale-forming salts, which, if high, would prevent the proper heat exchange in the boilers and condensers. The water should be free from iron which would cause a red core in the center of the cake, and it should also be free from excessive organic matter which would cause an odor in the ice. Water for the manufacture of plate ice should be low in magnesium salts, free from color due to organic matter, and free from sewage contamination.



GARBONDALE TUBULAR TYPE REFRIGERATING MACHINE.

The heat exchanger is horizontal, of the shell and coil type. The cooling water enters the double pipe condenser at the bottom, then passes through the absorber tubes; from the absorber it passes through the weak liquor cooler, and finally to the rectifier.

AMMONIA ABSORPTION SYSTEM.

The absorption and expulsion of ammonia gas by water forms the basic principle of the absorption refrigerating process. The first experiments and successful results in the work of "producing cold," or abstracting heat, by mechanical means, were accomplished upon this principle, by an apparatus whose action may be diagrammatically represented, as shown on page 306.

Describe the general principles of the Ammonia Absorption System.

Two vessels, A and G, of proper strength to resist internal pressures of 10 to 15 atmospheres (140 to 220 lbs. per sq. in.), are connected at their tops by a pipe, E. The smaller vessel G is inclosed within a jacket F, through which and around G cold water is circulated, entering at H and leaving at I. The larger vessel A is partially filled with a strong solution of aqua ammonia and heat is applied as by a fire underneath the vessel A.

As the ammonia warms, ammonia gas is driven off and fills G through the pipe E, air being allowed to escape from the system through a suitable opening in the bottom of G. When ammonia gas begins to issue strongly from this opening, the escape is closed by a cock D provided for the purpose.

Since the volume of gas in solution in the liquor in A is many times that of the water itself, the continued application of heat drives off such quantities of the gas as to create a constantly increasing pressure in the system. Just as in the case of water, ammonia has for every pressure a corresponding temperature of boiling and of liquefaction, at which temperature ammonia gas will liquefy if heat be abstracted from it, and ammonia liquid will gasify if heat be added to it.

If the cooling water has a temperature of 60° F., and maintains the vessel G and its contents at a temperature of, say, 65° F., it is evident that when the pressure of the gas within G reaches about 103.33 lbs. per sq. in. by gauge (118.03 lbs. absolute), the further expulsion of gas from the liquor in A causes a corresponding liquefaction of ammonia in G, and by continuation of the process an accumulation of liquid ammonia results in G until all the gas has been driven off from the water in A, the pressure remaining constant during the process and the latent heat of liquefaction being carried away by the cooling water flowing out at I.

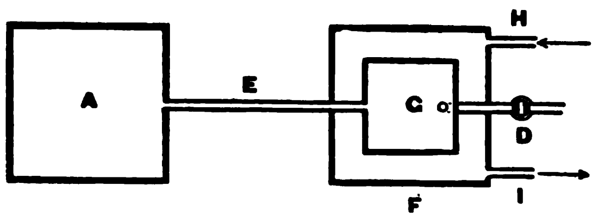


Diagram of elementary vacuum refrigerating system.

When the distillation of ammonia into G is completed, the process may be reversed by cooling A. This enables the water in A to absorb and dissolve the gas in contact with it, creating an immediate flow of gas from G and causing a reduction of pressure in the system. This decrease of pressure lowers the boiling temperature of the liquid ammonia in G, and consequently it at once starts to gasify. Now as, in liquefying, the ammonia yielded up its latent heat to the cooling water in C, so, in gasifying, heat must be abstracted by the ammonia from its surroundings. Hence, if the flow through C be stopped, the water remaining around G will be cooled and ultimately frozen. If then a brine whose freezing temperature is low, be substituted for the water in C, it may be piped away for cooling storage space or may freeze cans of water immersed within it for ice-making purposes.

Does this theory correspond with that used in practice ?

This original and elementary apparatus is intermittent, due to its necessity for reversing, and the construction and operation of a modern absorption refrigeration system involves the problem of making the process continuous. The basic principles of such a continuous system, as included in actual modern practice

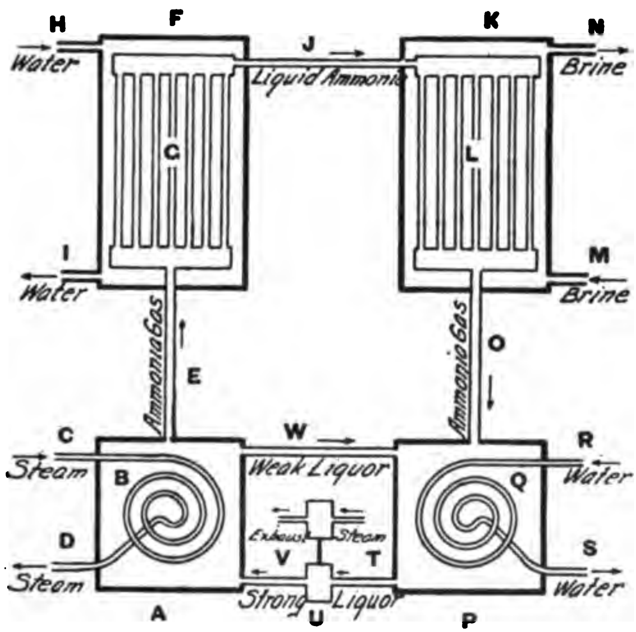


Diagram of elementary absorption system.

may be illustrated by above figure. Here A is the generator, also called the ammonia boiler or ammonia still, through which passes a pipe coil B connected with a source of steam supply. Steam circulates through this coil, entering at C and leaving at D. Strong aqua ammonia enters, through the

pipe V, the space in A around the coil. The heat from the steam coil drives off the ammonia as a gas, through the pipe E to the condenser F, while the weakened solution passes out through the pipe W. The gas, passing through the condenser coil G is liquefied, giving up its latent heat to the cooling water entering the condenser at H and leaving at I. The liquid ammonia flows through the pipe J to the refrigerator K, where it is gasified in passing through the coil L, absorbing heat from the brine in the refrigerator, entering at M and leaving at N. The refrigerator here represents a brine tank connected at M and N with the circulating system of cooling rooms or with ice-making tanks.

In either case the effect of the refrigerator is the same : the liquid ammonia is gasified by heat abstracted from the substance or substances cooled, either directly or through the brine as an intermediary.

Leaving the refrigerator K by the pipe O, the gas enters the absorber P where, under the cooling influence of the water coil Q, it is readily dissolved by the weak liquor entering through the pipe W from the generator A, as already described. Circulation of cold water, entering at R and leaving at S, is maintained through the cooling coil Q. The ammonia having been absorbed, the resulting strong liquor is passed through the pipe T, the pump U and pipe V to the generator for a repetition of the cycle.

Here, by doubling the extent of the apparatus on page 306, supplying a separate device for performing each of the several operations of the complete process, and providing a pump for maintaining the circulation of the liquor, a continuously working system is obtained. The vessel A of page 306 is, on page 307, replaced by the generator A and the absorber P, while the vessel G and its envelope F, are represented by the coils G and L and the tanks F and K of the condenser and refrigerator, respectively, in the figure on page 307.

Steam in the generator coil B, (or other power medium with heat as its original source) for actuating the pump U, and the brine or other cooled substance in the refrigerator K, contribute to the system certain amounts of heat all of which are absorbed and carried away by the cooling water in the condenser F and the absorber P. The efficiency of the system as a refrigerating process may be expressed as the quotient of the heat supplied by a steam boiler to the generator and pump, divided by that abstracted in the refrigerator. In a steam engine, heat supplied by the fuel is partly converted into work, the remainder being carried away in the exhaust and lost in the atmosphere or the condenser. The thermal efficiency of the engine is, then, the quotient of the heat supplied by the fuel divided by that converted into work.

The refrigerating system, while in one sense directly the reverse of the heat motor, yet bears very evident analogy to it, the difference being, as already indicated, that the heat motor receives a supply of heat, a portion of which it converts directly into work, while the refrigerating system receives its supply of heat for use in abstracting heat from some substances, through the agency of a refrigerating medium.

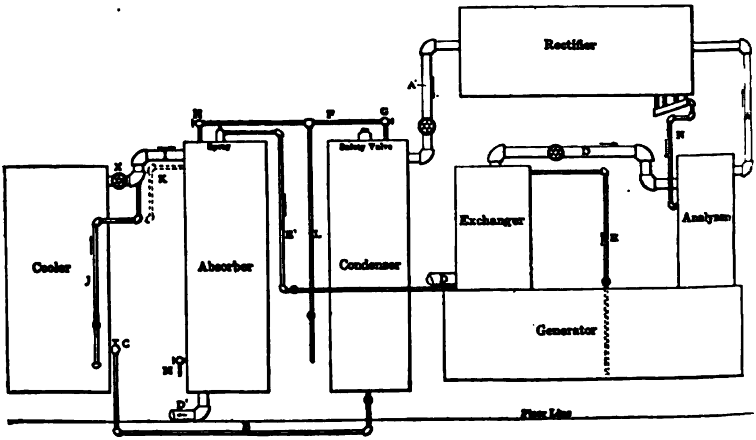
An actual apparatus for refrigeration by the ammonia absorption process necessarily involves various details and items of equipment not indicated among the essentials as represented by the figure on page 307 ; however, this crude form is capable of performing actual work although of low efficiency.

How old is the absorption system ?

It was brought out by F. Carre in 1861, but the development of his elementary plan into complete, durable, and economical machines has cost much time, experiment, brains and money, and to lay out a plant properly adapted for a particular place and service calls for technical knowledge and experience in this special branch of engineering.

What are the important parts of the Absorption system and peculiar to it?

1, the Generator; 2, the Analyzer; 3, the Rectifier; 4, the Heat Exchanger; 5, the Heater; 6, the Weak Liquor Cooler, 7, the Absorber, and 8, the Ammonia Pump.



Diagrammatic elevation of complete absorption plant. The ammonia is evaporated out of the rich liquor in the generator and analyzer, and passes off into the rectifier through the pipe A^1; from the rectifier the gas passes to the condenser through the pipe A. The anhydrous ammonia passes through the pipe B and expansion valve C to the cooler. The ammonia vapor is led by means of the pipe I and valve X to the absorber into which the poor liquor is sprayed through the pipe E^1, coming from the exchanger. L–F is the water pipe for the condenser and absorber, the flow being regulated by means of the valves G and H. The rich liquor is taken from the absorber by the pump through the pipe D^1 and discharged through the exchanger into the analyzer through the pipe D. The poor liquor is forced by pressure from the generator through the pipe E and through the exchanger. J is the purge pipe of the cooler. N is the drip from the rectifier.

What is the only moving piece of machinery?

The Ammonia Pump, which runs at comparatively low speed; every thing else consists chiefly of heavy steel cylinders or shells containing coils of pipe.

Can copper be used in the coils or valves of an Absorption machine ?

The action of ammonia on copper, or its alloys like brass, is such that its use in an ammonia machine is out of the question.

How are the coils tested after having been in use ?

For testing the coils, the aqua ammonia must be withdrawn, the vessels opened, one end of each coil closed and provided with an air cock, and the other end connected with the discharge pipe of the ammonia pump. A correct pressure gauge being placed after the discharge valve in the pressure line, each coil is subjected to a hydrostatic pressure of from 250 to 300 pounds per square inch. While pumping the coil full of water, the air cock must be open to allow the air to escape, after which the cock is closed. As soon as the desired pressure is obtained, the discharge valve is closed so that the gauge can register any reduction.

If the gauge does not go back, the coil is tight, but if the gauge shows a loss of pressure and continues to do so, repeat the pumping up as done before, and if observing another loss of pressure, leaks surely exist, and the coil should be taken out and tested again in order to find the leaks, which may be repaired by soldering and clamping, or if they are too bad or too many in number, the coil should be replaced by a new one.

After all the coils are tested in this way, independently, and properly repaired, they must be assembled and all the coils of one apparatus tested once more in the same manner as a whole, to make sure that all the new connections are tight. Then the vessels can be closed again, and in doing this, all the gaskets should be renewed, whether they are of rubber or lead, because the old ones are usually damaged or have lost their elasticity.

What affects the coils ?

While anhydrous ammonia will not affect iron or steel, aqua ammonia **does** act upon the metal in some degree.

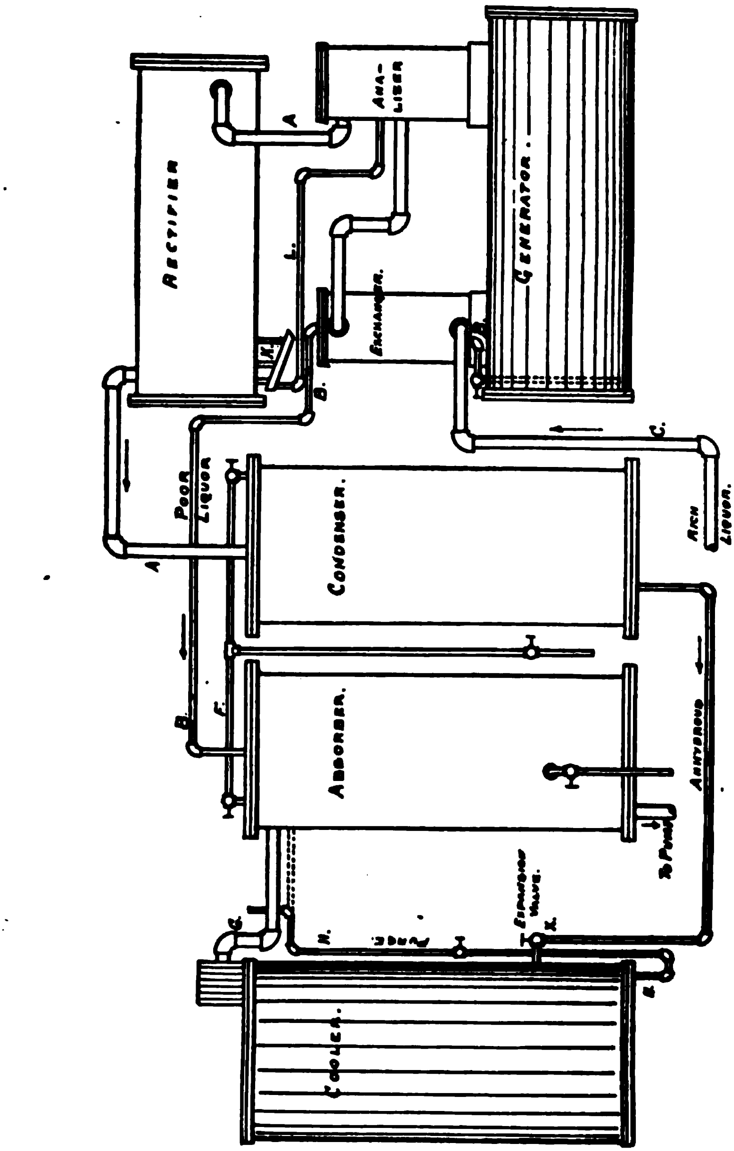


Diagram of absorption system, similar to that on page 310.

Give a description of the Generator.

This apparatus, also called the still or retort, is a large heavy shell or cylinder which should be capable of standing a pressure of 500 pounds per square inch.

It may be placed horizontally or vertically, its distinguishing feature in the interior being a steam coil which heats the strong ammonia liquor that is taken from the absorber by the ammonia pump and forced into the generator through the analyzer.

What is an objection to the vertical generator?

Like the vertical boiler the evaporating surface being so small it will not make dry gas. The boiling is very rapid, and it is difficult to keep the steam coils always submerged.

It also requires excessive head room, and a "boil over" is more likely to occur than with a horizontal generator.

How are the coils arranged in the generator?

The coils occupy about half the height of a vertical generator, and a hood or inverted cone should be placed over them so that if the level of the liquor should fall so as to expose them that the rich liquor will not fall on them.

What is the temperature of the generator liquor?

It reaches the analyzer from 150 to 170 degrees F. and is about 200 degrees when it reaches the boiling liquor in the bottom of the generator.

What is the latent heat of vaporization of ammonia, and its vapor tension?

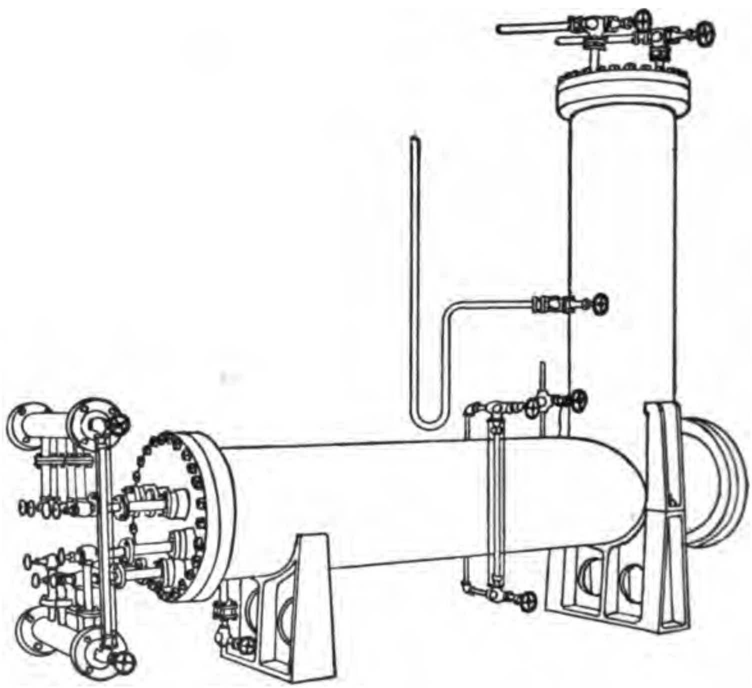
Nine hundred heat units and 128 pounds per square inch at 60 degrees Fahr.

What is the pressure in the generator coils?

With live steam the pressure usually varies from 10 to 20 pounds; with exhaust steam about 5 pounds.

When does ammonia decompose?

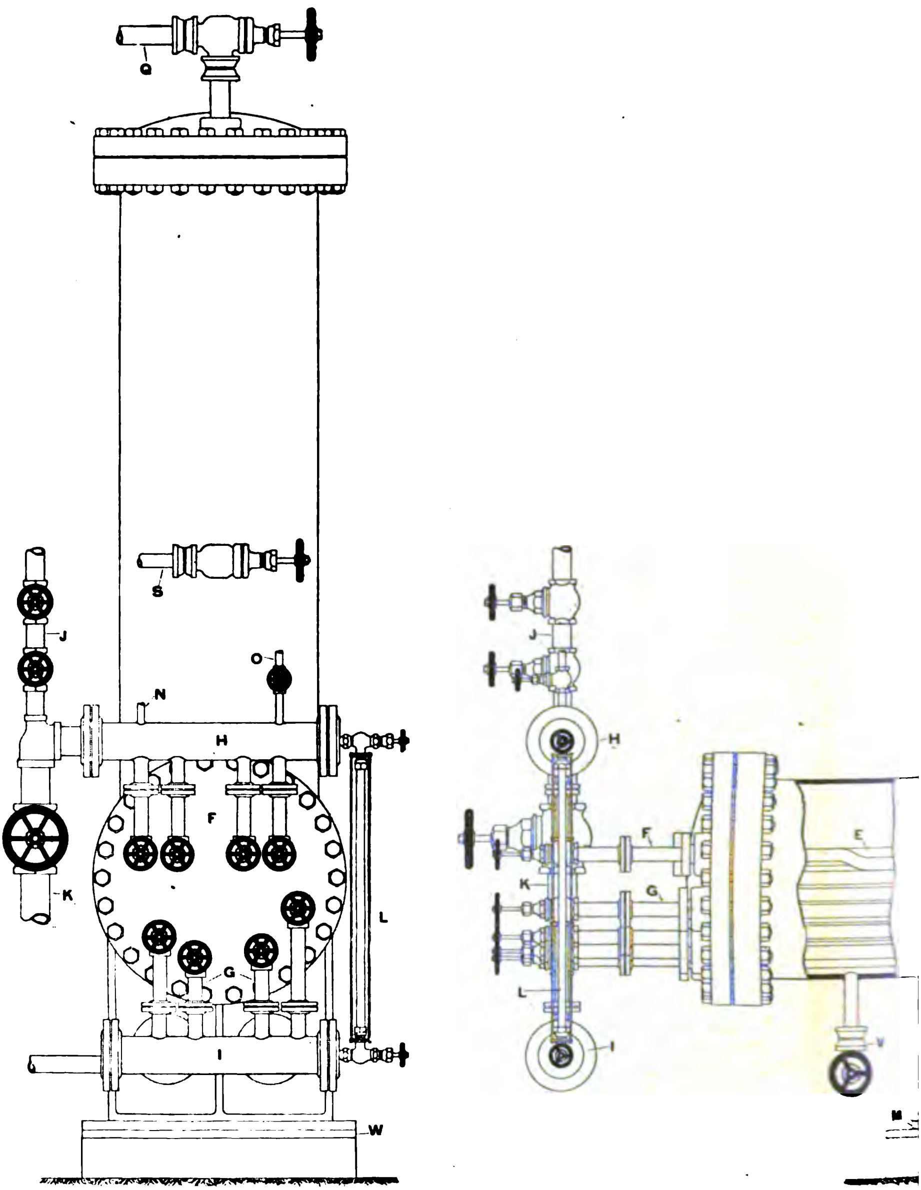
It dissociates at 900 degrees Fahr., and under certain conditions partial decomposition may take place at lower tempera-



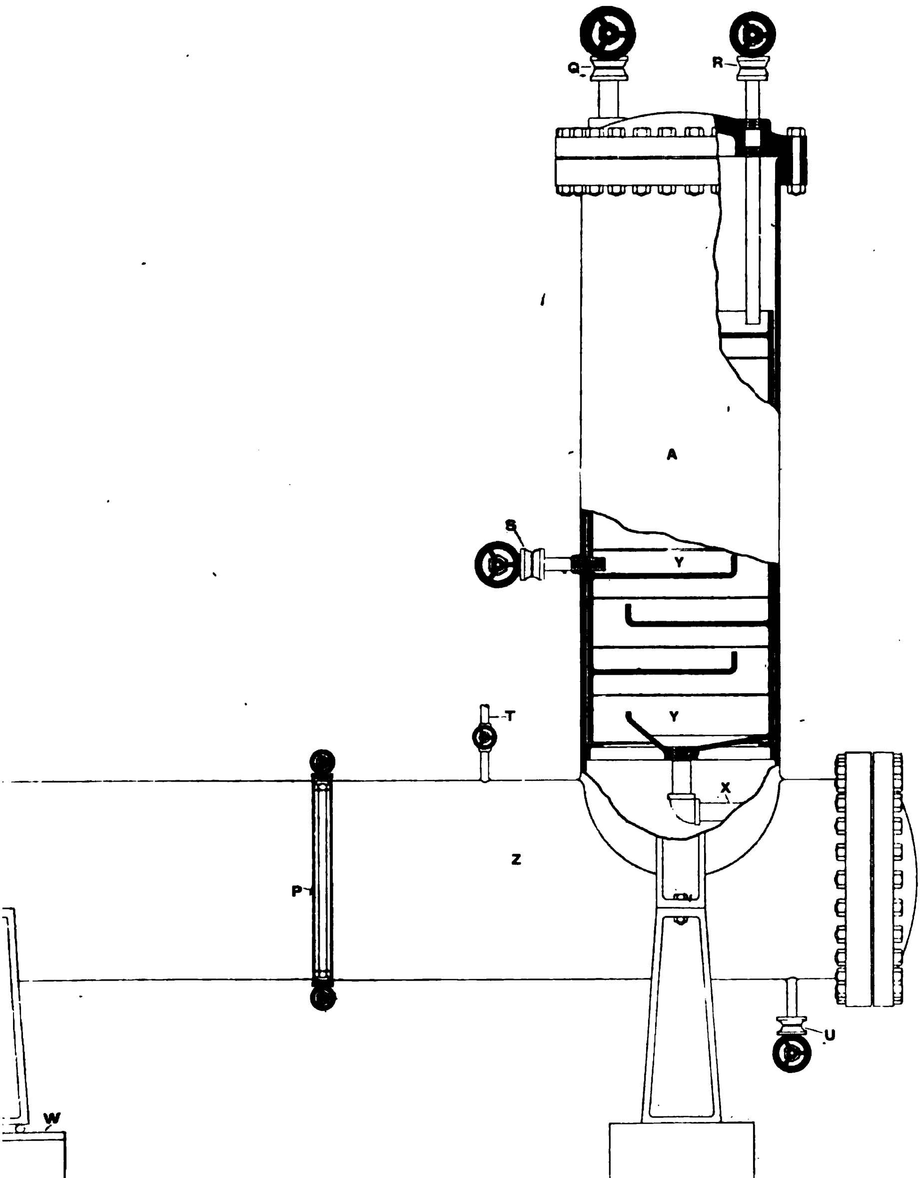
The York generator with analyzer shell welded to the generator body. The longitudinal seams are also welded which makes an absolutely seamless construction.

A partial cross-section, showing detailed description and end elevation of this generator and analyzer, is shown on the colored insert, opposite. It is especially constructed to be used with the York ammonia pump described on page 345.

tures, so that its temperature should not be allowed to run up over 300 degrees Fahr.



York Generator and Analyze



ɪr description see page 315.

YORK GENERATOR AND ANALYZER.

(See colored insert).

The York Coil Generator and Analyzer with welded seams. This generator is adapted for exhaust or live steam. The exhaust steam enters at K and the live steam through the pipe J; both being connected to the manifold H which is provided with a pressure gauge connection N and a purge O for blowing off air.

The manifold H connects with the branch pipes F which lead through stuffing boxes in the generator head, and form the ends of the steam coils E. Each branch is provided with an independent stop valve, so that any of the coils may be cut out in case of leakage.

The outlets G of the steam coils connect with the manifold I to which the drain pipe is connected, the water of condensation being returned to the boiler or in an ice plant it is led to the storage tank. The upper and lower manifolds are connected by means of a gauge glass L to show the level of the water of condensation.

The strong liquor enters the analyzer A through the pipe R and flows over the pans Y where it gives up a large percentage of its gas by coming in contact with the rising hot gas. The liquor is then discharged into the generator Z through the pipe X, and is freed of most of the ammonia by the heat of the steam coils E. The gauge glass P indicates the level of the liquor in the generator. The weak liquor leaves the generator through the pipe V and is passed through a heat exchanger on its way to the absorber.

Q is the discharge for the gas, which is passed through the rectifier or dehydrator; the drip of same is returned to the analyzer at S. U is a drain to clear the generator of sediment and T is a pressure gauge connection.

The generator is mounted upon cast iron pedestals, one of which is stationary, while the other is placed upon rollers M which are free to roll on an iron plate W, and thus any strains due to expansion and contraction are avoided. The manner of attaching the heads is clearly shown in the illustration; the shell is flanged over and provided with a ring which takes the bolts.

If steam is admitted to the generator at a temperature of 270 degrees F., why is not the water driven off with the ammonia ?

Because the increase of pressure, say 160 pounds, raises the boiling point of the water.

How does the steam pressure of the generator compare with the condensing pressure ?

It is usually about one-third.

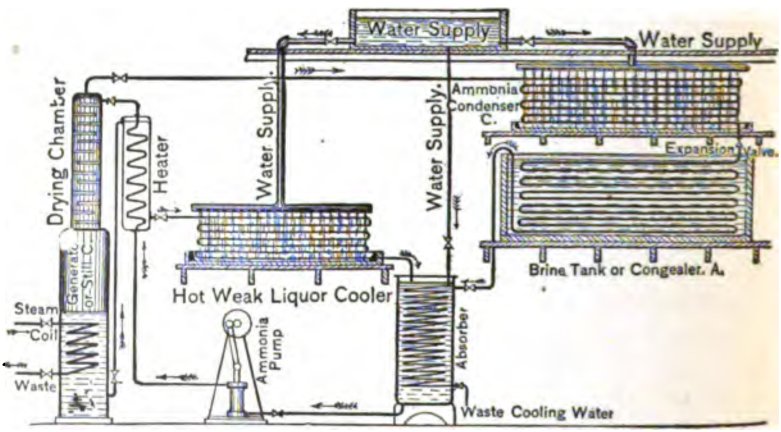


Diagram of absorption system with vertical generator, weak liquor cooler, and brine tank.

What connection does the generator have with other parts of the system besides the analyzer ?

An outlet is provided in the lower part for taking the weak liquor back to the absorber.

In case of a disturbance or stoppage of an absorption machine what should be done first ?

The steam should be shut off the generator.

What level of strong liquor should be maintained in the generator?

It should always be kept above the upper coil, otherwise there is danger of producing a chemical change in the ammonia and forming permanent gas; the falling of the aqua ammonia on the bare pipes may also cause pitting of the pipes.

NOTE.—Watch the gauge at the end of the generator and see that the liquid does not get below the top of the tubes. There should be a mark at the end of the generator near the glass so that the amount can be seen at any time. It is a good idea also to have a gauge marked in inches placed beside the glass so that any change may be seen at a glance.

What does the Absorption system require in the way of repairs?

Repairs are mainly confined to stopping leaks in pipes and connections, renewing gaskets, and, when necessary, replacing old coils with new ones.

About what is the life of a coil under ordinary working conditions?

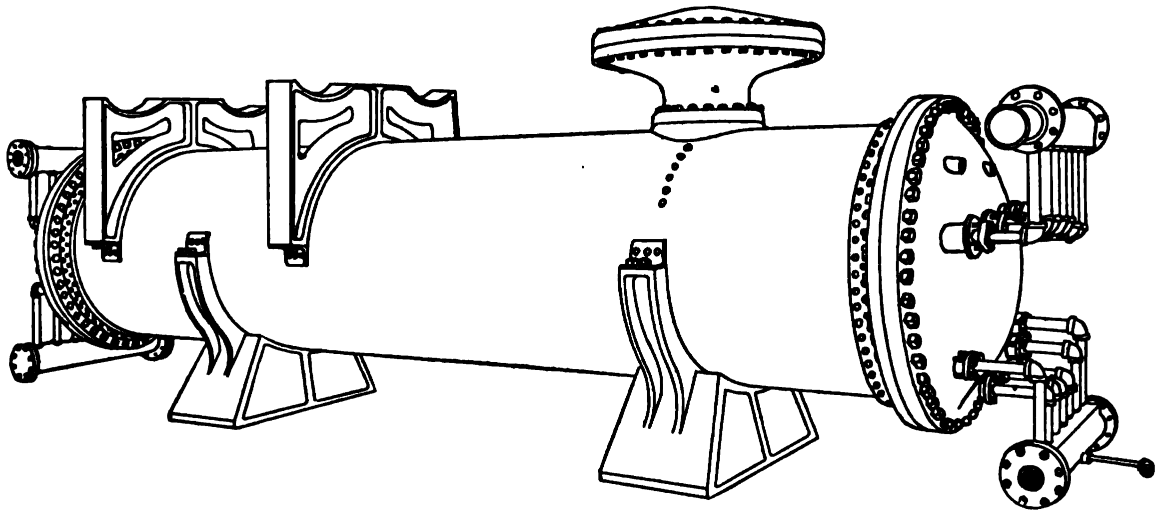
After from three to five years use they should be carefully examined and tested every year, especially those in the generator and absorber. After a service of six or eight years they may be eaten through in spots by the action of the aqua ammonia.

What is the principle on which the generator operates?

Heat, by means of the steam in the generator coil, is brought to bear on the strong liquor in the generator, because ammonia will evaporate at a lower temperature for a given pressure than water, consequently in theory the ammonia gas rises and, becoming stronger as it ascends, finally passes off through the upper part of the analyzer, leaving the water in the generator.

How thoroughly can the water be taken out of ammonia gas?

The percentage can be reduced as low as .025.



The Carbondale generator in course of erection before the attachment of the heat exchanger and analyzer. It will be noted that the cover of the analyzer is temporarily bolted upon the foot of the same, which is done to submit the generator to hydrostatic pressure. Every part of a plant should be thus tested independently before connection.

How is this theory affected in practical operation ?

In actual working some watery vapor will be carried along with the ammonia.

Should Generators be examined periodically ?

Generators should be opened and thoroughly examined internally ; especially is this necessary where cast iron comes in contact with the hot aqua ammonia, as it is well known that cast iron deteriorates under such conditions. Should the tubes or coils be incrusted by reason of impurities in the aqua ammonia, they must be thoroughly cleaned, particularly if only exhaust steam is used, as this means a lower pressure and of course a lower temperature.

What special precaution should always be taken to prevent a "boil over" ?

The generator gauge glass should be closely watched to see that the coils are always covered with liquor.

What is a "boil over" ?

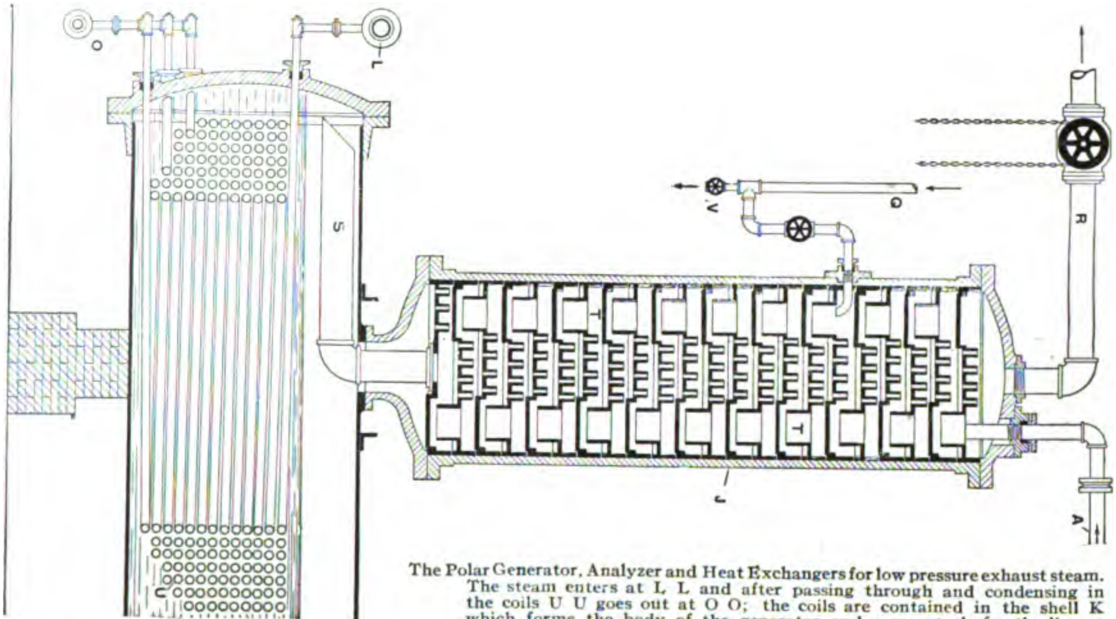
When the ammonia charge in the generator is drawn out of it into other parts of the system ; it may be caused by an insufficient charge in the system, by defective working of the pump, or some derangement in operating conditions.

Should great care be taken not to force an absorption machine ?

Yes, for it would be very likely to derange the working of the various parts of the system, and might cause a "boil over."

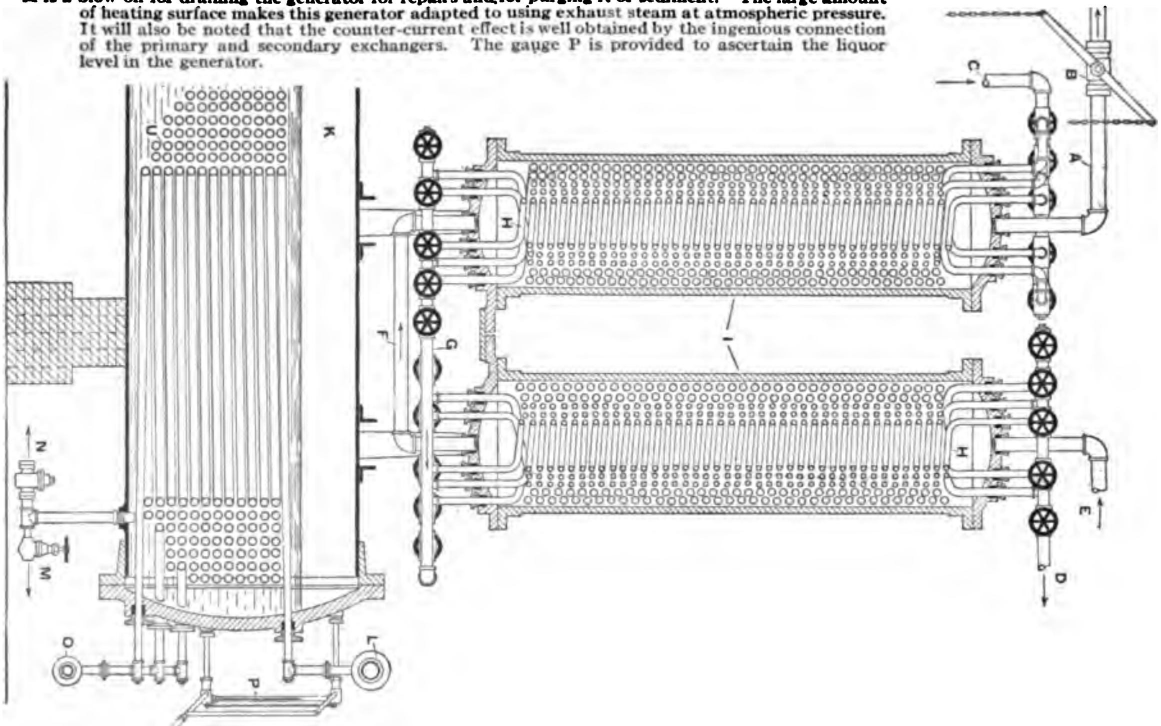
What peculiar advantage has the absorption machine ?

The use of lubricating oil required in a compressor is avoided, and as the spent steam from the generator is distilled water when condensed, it requires no oil separator, or other purification process, if the boiler feed water is of satisfactory quality.

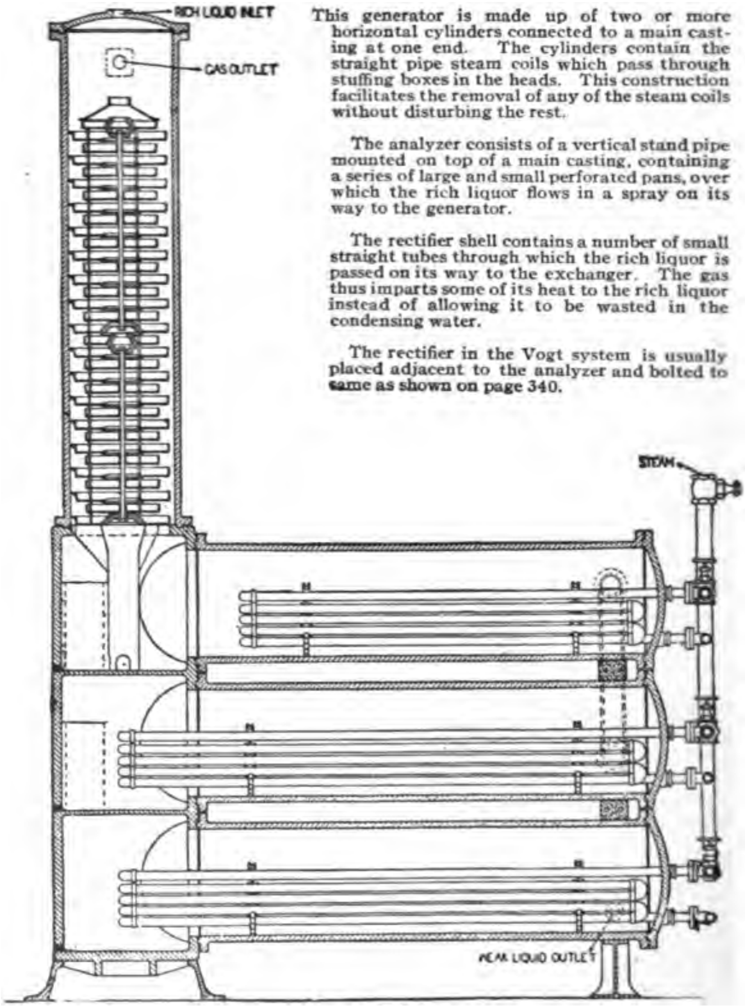


The Polar Generator, Analyzer and Heat Exchangers for low pressure exhaust steam. The steam enters at L L and after passing through and condensing in the coils U U goes out at O O; the coils are contained in the shell K which forms the body of the generator and a receptacle for the liquor. The rich liquor from the ammonia pump enters at E, and after passing through the exchangers I and the pipe F, is led to the analyzer J by means of the pipe A. The pipe A is provided with a stop cock which can be quickly operated by means of chains attached to a lever. In the analyzer the rich liquor flows over a number of pans T, where it comes in contact with the rising hot gas, and after circulating over all these pans it drains into the generator through the pipe S. The vapor from the analyzer passes to the rectifier by means of the pipe R; the rectifier drip Q enters the analyzer, as shown, and is provided with a drain V for blowing off. The weak liquor leaves the generator at N and enters the exchanger coils H at C; after going through the primary exchanger it passes by means of the manifold pipe G through the secondary exchanger coils and header pipe D to the weak liquor cooler, and finally into the absorber where it again unites with the anhydrous vapor. (See also on opposite page).

M is a blow-off for draining the generator for repairs and for purging it of sediment. The large amount of heating surface makes this generator adapted to using exhaust steam at atmospheric pressure. It will also be noted that the counter-current effect is well obtained by the ingenious connection of the primary and secondary exchangers. The gauge P is provided to ascertain the liquor level in the generator.



Sectional Elevation of 150 Ton Vogt Generator with Analyzer.



This generator is made up of two or more horizontal cylinders connected to a main casting at one end. The cylinders contain the straight pipe steam coils which pass through stuffing boxes in the heads. This construction facilitates the removal of any of the steam coils without disturbing the rest.

The analyzer consists of a vertical stand pipe mounted on top of a main casting, containing a series of large and small perforated pans, over which the rich liquor flows in a spray on its way to the generator.

The rectifier shell contains a number of small straight tubes through which the rich liquor is passed on its way to the exchanger. The gas thus imparts some of its heat to the rich liquor instead of allowing it to be wasted in the condensing water.

The rectifier in the Vogt system is usually placed adjacent to the analyzer and bolted to same as shown on page 340.

What is the Analyzer ?

The analyzer is an upright cylinder placed upon the generator, if the latter be a horizontal one, or practically forming the upper part of it if it be a vertical one.

It is sometimes made part of a horizontal generator.

What is the operation of the Analyzer ?

Arranged in its interior are a series of shelves and a corresponding number of basins below them. The strong liquor is forced into the upper part of the analyzer by the ammonia pump, and as it falls on the boiling liquor below it passes over these plates and basins and the vapor passing upward increases in strength, while the strong liquor passing downward is constantly rising in temperature. The channels of the analyzer must be large enough to allow this passage without foaming or interference.

What, practically, is the combined function of the generator and analyzer ?

To separate the ammonia gas from the water which has taken it up in the absorber.

Should care be taken to keep the analyzer in good condition ?

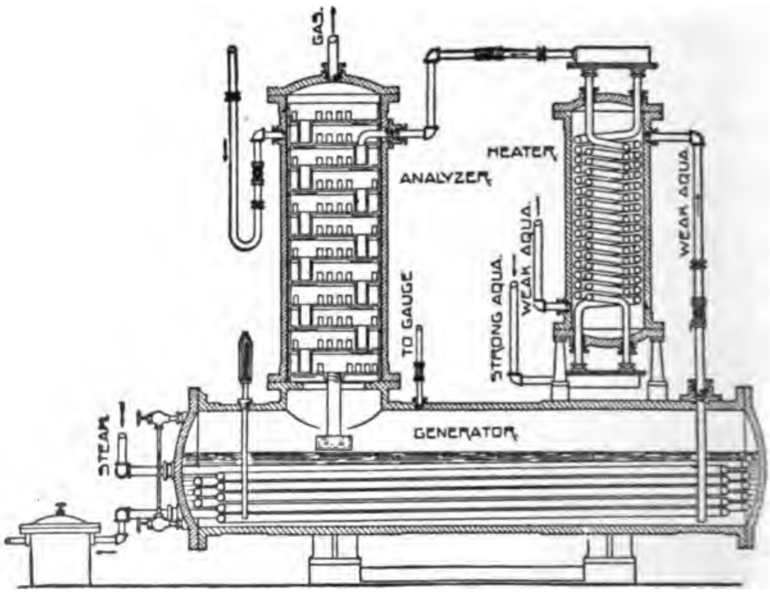
The analyzer should be kept clean, for if the trays become clogged their capacity for handling the liquor is lowered, the analyzer will become flooded, and the ascending gas will carry liquor over to the rectifier.

Where does the ammonia gas go after passing through the analyzer ?

The gas is destined for the condenser, the same as when it leaves the compressor of a compression machine, but as it is always sure to contain some watery vapor it first passes through an apparatus called a rectifier, with a view to taking out the last trace of moisture.

Describe the Rectifier.

It is a small coil partly surrounded by water ; as the gas cools the small quantity of liquor that may be condensed from the gas goes to the ammonia pump. It is also called a dehydrator.



Sectional elevation of Polar generator for live steam. This generator differs from the one on page 320, which is built for exhaust steam, in the amount of heating surface, and arrangement of the steam coils.

Where do the water and gas enter ?

The gas inlet is at the top and the outlet at the bottom, the water taking the opposite direction.

Does the Rectifier require close attention ?

The efficiency of the machine depends very largely on the proper working of the Rectifier. If it is not kept at the proper temperature there will be trouble. If it is allowed to run too hot the moisture held in suspension by the gas will not be removed, and will pass into the condenser and liquefy with the gas. If it is run too cold both the moisture and the gas will be condensed and returned to the generator, leaving no gas to go to the condensers to supply the cooler. If it is allowed to become too cold it may cause a "boil over."

How can the workings of the rectifier be watched ?

By a thermometer which should not vary much from 110 degrees. The drain pipe should feel warm to the hand.

The water supply, which can be by-passed, if necessary, should also have a thermometer so that the supply can be regulated.

What is the objection to a small amount of watery vapor in the gas ?

A very small percentage of moisture in the gas cuts down the capacity of the plant in a large degree, and great care should be taken by the engineer to see that the analyzer and rectifying apparatus are in perfect operating condition at all times.

What is the effect if the rectifier does not work properly ?

When the machine is working properly the rectifier will take all moisture out of the gas, and it will be dry and clean. But if there is more moisture than the rectifier can separate, this moisture must go to the condenser and from there to the cooler, and moisture will not evaporate in the cooler, but takes up room and interferes with the evaporating ammonia gas, and must be purged before the machine will do good work.

Where does the dry gas go after leaving the rectifier ?

It now passes into the condenser.

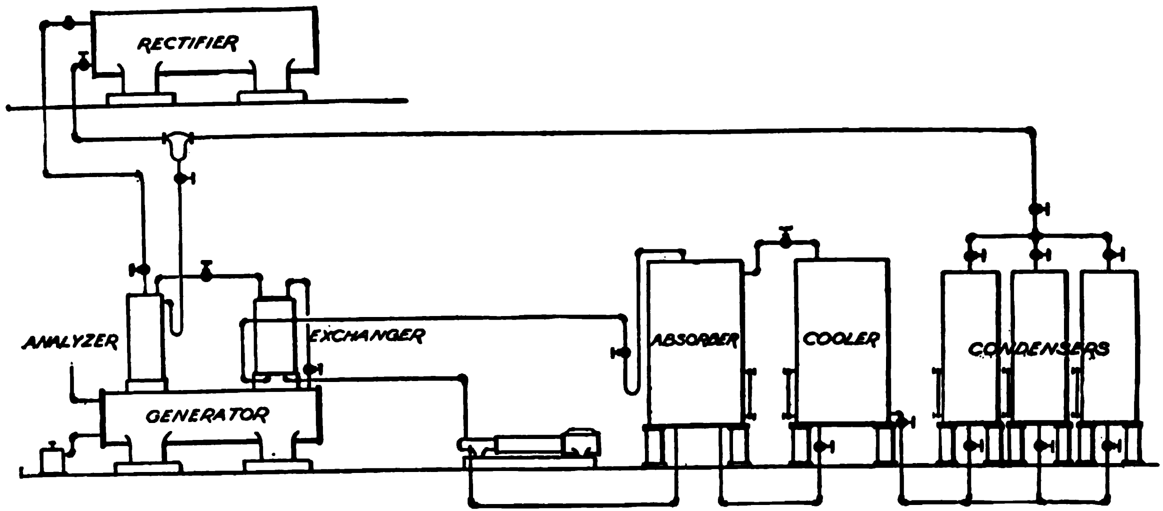


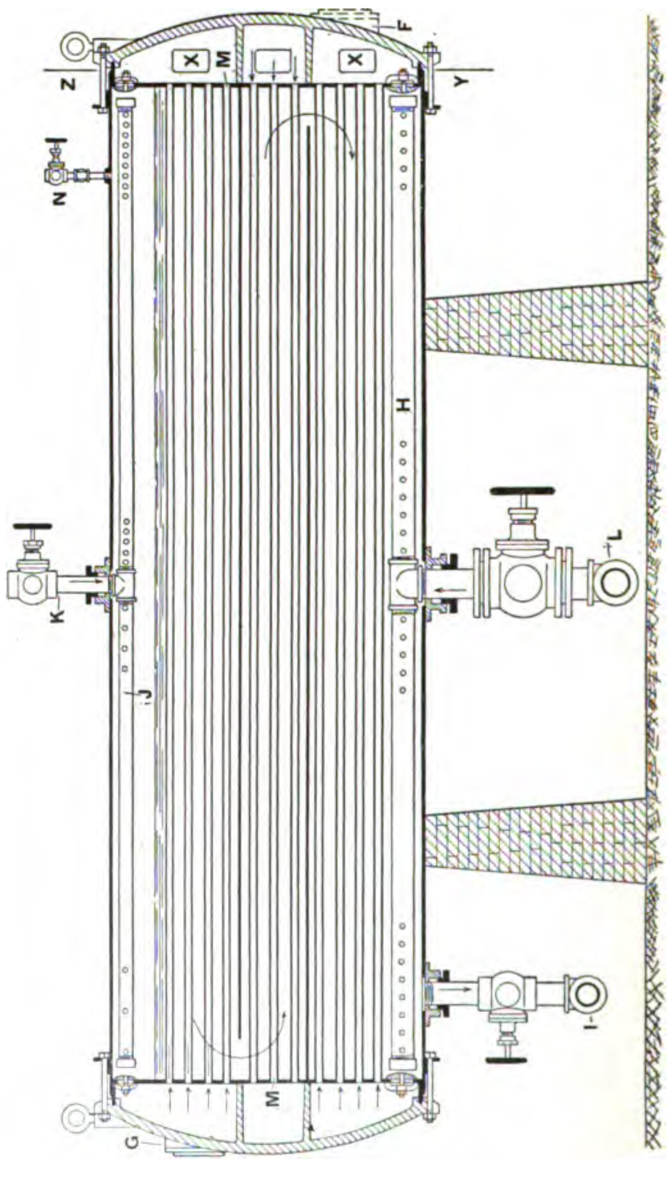
Diagram of Polar absorption system with shell and coil condensers.

If an engineer should suspect that his rectifier was not working properly how could he test the ammonia for water?

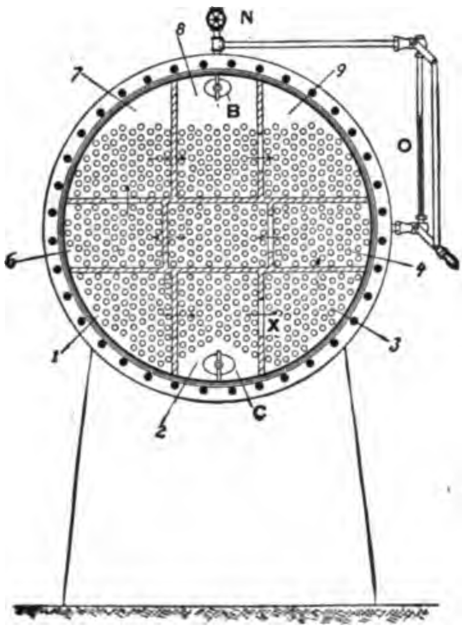
A test should be made by taking a 12-inch glass test tube, or, if this cannot be had, a 1-inch pipe about 12 inches long capped at one end. Bend a piece of wire about a foot long around one end of the tube or pipe so that it can be held away from the hand. Take a piece of pipe about the same size as the cock on the ammonia receiver and bend the threaded end so that the pipe will stand vertical when in position on the drum. Slip the test tube over the pipe until the end reaches almost to the bottom of the tube. Open the valve gently and draw a certain number of inches of liquid anhydrous ammonia into the tube, withdrawing it from the bent pipe as it fills. After noting carefully the amount of liquid in the tube, pour it in a shallow vessel and set the vessel in cold water or on a block of ice. Under these conditions, the ammonia will evaporate quickly and any residue remaining is the amount of moisture and impurities originally in the ammonia. Divide the amount of residue by the quantity of liquid drawn into the tube and multiply the quotient by 100, which gives the percentage. Before the liquor is drawn into the tube, a little gas should be allowed to escape in order to purge the test pipe.

Why is the water supply an important factor in an absorption machine?

Because a good supply is required not only for the condenser but for the absorber. To operate a refrigerating plant with any degree of economy, a copious supply of condensing water is required. It is as much the life of the plant as the fuel. A plant without an abundant supply of cheap cool water cannot be operated economically. The higher the temperature of the condensing water, the greater the amount of power necessary to operate the plant. The condensing water is the sole means of escape of all the heat abstracted in refrigeration.



Polar Horizontal Absorber; for explanation, see page 329.



The Polar Horizontal Multitubular Absorber. (See pages 328 and 329). The weak liquor enters the top of the absorber through the pipe K and is distributed by means of the sprinkling pipe J. The anhydrous vapor coming from the coolers enters at L and is distributed by the perforated pipe H ; both pipes are provided with caps at their extremities, which may be removed after opening the handholes B and C, and thus be cleaned out with a tube cleaner and a hose.

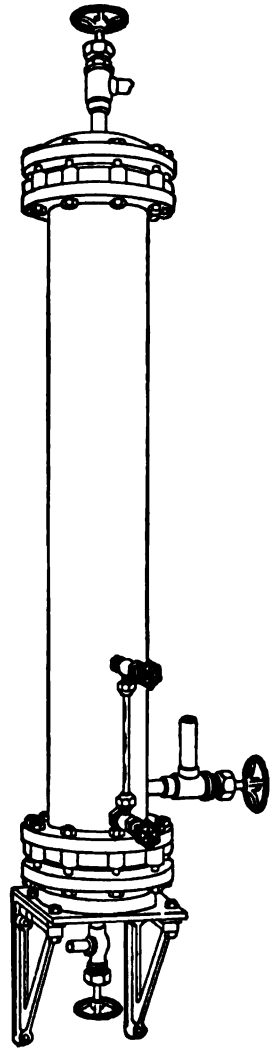
The weak liquor is compelled to pass all the absorber tubes M by being deflected from a direct downward course by the baffle plates, as shown. The flow is sufficiently slow to give the rising gas ample time to come in contact with the strengthening liquor and be fully absorbed.

The cooling water enters at F, connected with the compartment 1 in the front head on this page ; it then passes through the row of tubes ending in this compartment ; then returns through another row of tubes to compartment 2 and through the first opening X enters compartment 3, and so on until it finally leaves the absorber at G.

The view on this page is a section through Y Z on page 328.

The strong liquor leaves the absorber through the pipe I, and being taken up by the ammonia pump is finally returned through exchangers and analyzer to the generator.

The liquor level in the absorber may be observed by the gauge O, and a pressure gauge should be connected to N



Ammonia receiver mounted on cast iron wall brackets.

How much more condensing water does the absorption system require than the compression system?

About two and one-half times as much.

Does the expansion valve require special attention in an absorption machine?

Care must be taken to regulate the expansion valve so that an excessive back pressure will not be created on the low side of the system. This is a matter to be watched very closely in an absorption plant. The best results are had with the pressure below 12 pounds. In this respect the absorption system differs from the compression machine very materially.

What is meant by head and back pressure?

These terms are applied, respectively, to the condensing and evaporating pressure of the ammonia.

What is the Absorber?

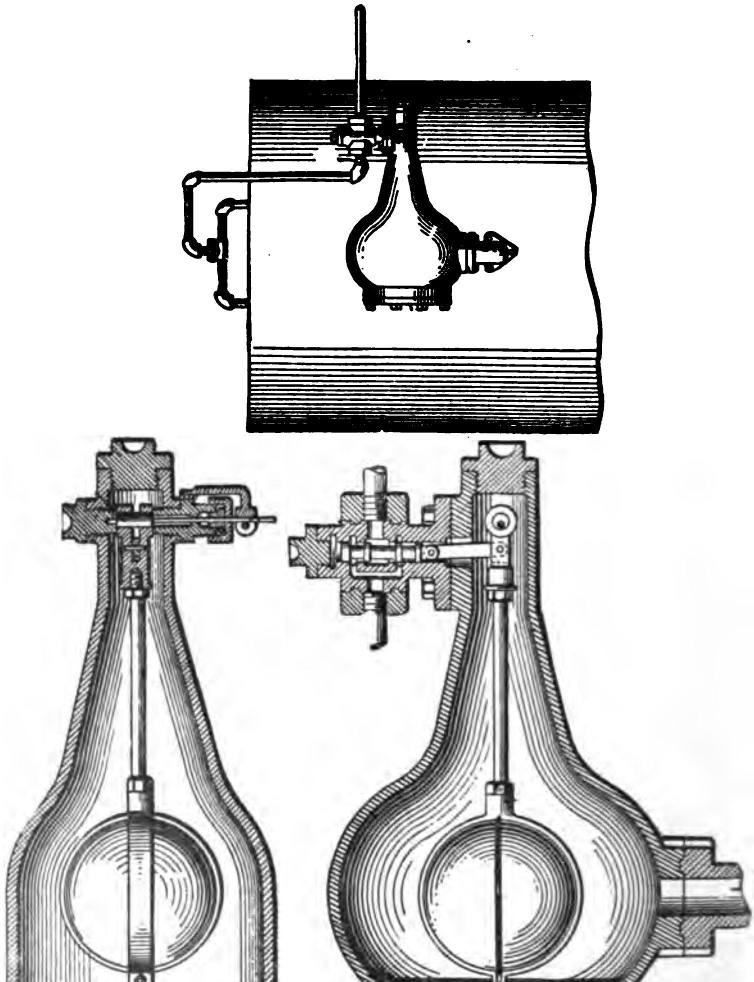
A cylindrical vessel or shell into which the vapor of ammonia as it comes from the refrigerating coils is led, and where it is mixed with the weak liquor which comes from the lower part of the generator. It may be of the shell and coil, straight tube, double pipe, or atmospheric type.

How is the weak liquor introduced into the absorber?

When the gas in the generator has been distilled it leaves the aqua weak, especially at the bottom, and this weak liquor is forced through the exchanger to the top of the absorber, where it is thrown over the incoming gas and the water coils in a spray, by means of a valve for that purpose at the top.

What is the course of the water circulation in an Absorption machine?

The cooling water, after doing its work in or over the condenser, according to the type used, flows through a coil in the absorber, then through the rectifier.



Weak liquor regulator. It is attached to the absorber so that the liquor will raise the ball if the liquor level should rise too high ; the ball being attached to a lever which controls a valve in the liquor pipe will shut this valve if the level rises and open the valve if the level falls.

Why is it necessary to pass cooling water through the absorber?

Because the lower the temperature of the weak liquor the greater its power to absorb the ammonia vapor coming back from the refrigerating coils.

How should the absorber be placed?

As near the expansion tank as possible.

How is the vapor introduced into the absorber?

The pipe conveying it is brought into the absorber about in the center, and should be so arranged that the vapor will not fall directly on the water coils.

How is the weak liquor sprayed at the top of the absorber?

There are many spraying devices; one is simply a valve with three oblique holes. If one side of the absorber gets warmer than the other, turn the valve slightly down, say one-eighth of a turn, and by a little manipulation the all-over temperature of the absorber can be maintained even. Sometimes a little scale or dirt will get over a hole and partly close the valve.

Does this spraying device regulate the flow of weak liquor?

This valve does not regulate the flow of the poor liquor, simply its distribution over the coils. The flow of the poor liquor is regulated by the valve near the exchanger, that at the generator being used only to shut off the poor liquor altogether. There should be only enough poor liquor thrown over to absorb the gas. More than this puts an extra load on the ammonia pump, exchanger and absorber.

How is the supply of weak liquor regulated as it enters the absorber?

Usually by valves, although there are automatic regulators.

Why is an automatic regulator desirable ?

While not absolutely essential in operating an ice plant, it is entitled to careful consideration, both from an economic standpoint and general comfort of the engineer. This apparatus, when once set, requires scarcely any attention, thus enabling the engineer to pay more attention to other matters. On the other hand, if the poor liquor entering the absorber is regulated by hand, he cannot leave the engine room with safety for any length of time, because the amount of poor liquor entering the absorber varies with both the generator and absorber pressures.

How is a regulator attached to an absorber ?

It can be adjusted so as to carry the liquid at the required height in absorber and generator. The adjusting can be made while the machine is in full operation and without disconnecting any parts.

The height of the liquid in the absorber can be regulated by turning an eccentric pin which extends through a stuffing box on the regulator body. If it is desired to carry more liquor in the absorber, the eccentric pin is turned to the right, and if less liquor is desired, it is turned to the left. It can be connected to absorption machines of any make, and will control automatically the weak liquid entering the absorber to mix with the return gas, thereby producing rich liquor of the proper strength.

How do the ammonia gas and poor liquor come together in the absorber ?

Generally they are mixed together in a manifold at the lower end of the coils.

What is usually the strength of the generator and absorber liquor ?

The strong liquor leaves the absorber at 25 to 30 degrees Beaumé, and the weak liquor leaves the generator at 18 to 20 degrees Beaumé.

How does the strong or rich liquor leave the absorber ?

It passes out at the bottom, through the ammonia pump, and from there to the exchanger, whence it goes to the analyzer on its way to the generator.

How may a leak in the cooling coils of the absorber be detected ?

A leak in one of the cooling coils of the absorber will at once be noticed in making a test of the cooling water after it has passed through the coils. Should a leak be indicated, steps should be taken to locate the defective coil at once, as in the case of a leaky coil in the generator. The main point of operation with the absorber is regulating the liquor level and it is now a recognized fact that the larger part of the attention required for doing this properly should be given by an automatic regulating valve for controlling the flow of the liquor. Air and burnt gases should at all times be kept purged off the absorber.

Why must the absorber be frequently cleaned ?

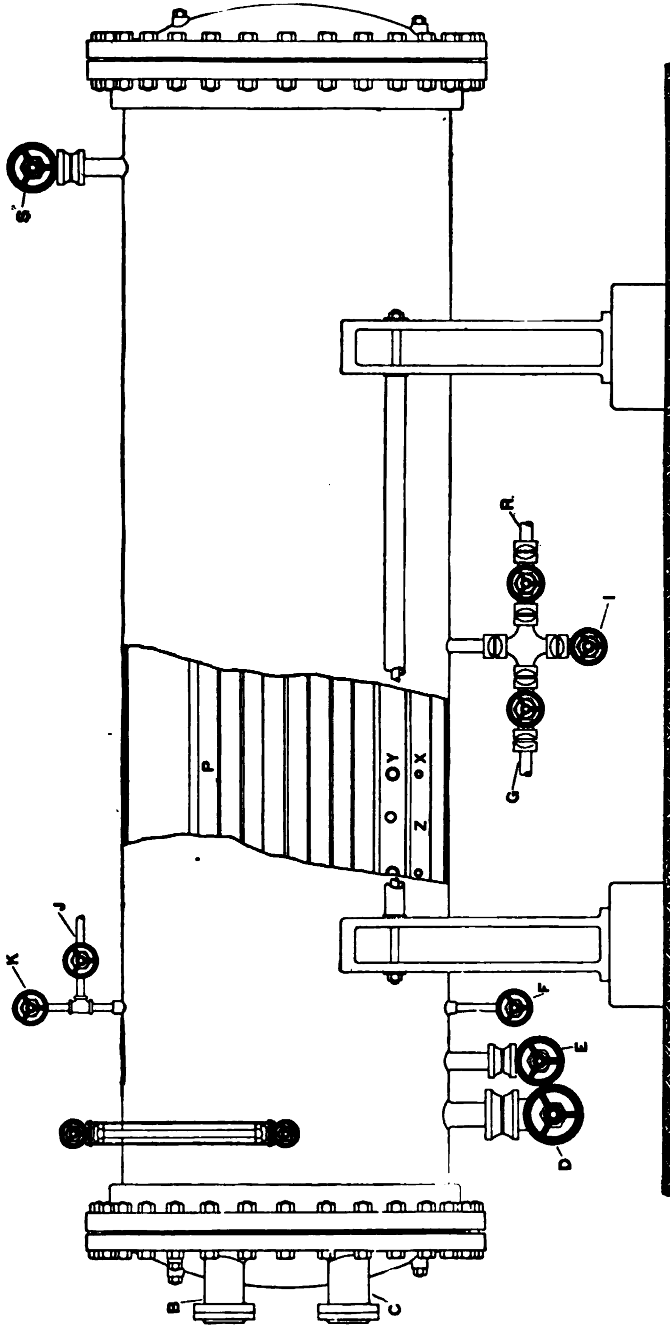
The cooling waters used in the operation f absorbers usually contain carbonates of lime, magnesia, and iron, which become insoluble at the temperature of the absorber because the free carbonic acid is driven off from the water which holds them in solution.

How may the absorber coils be cleaned ?

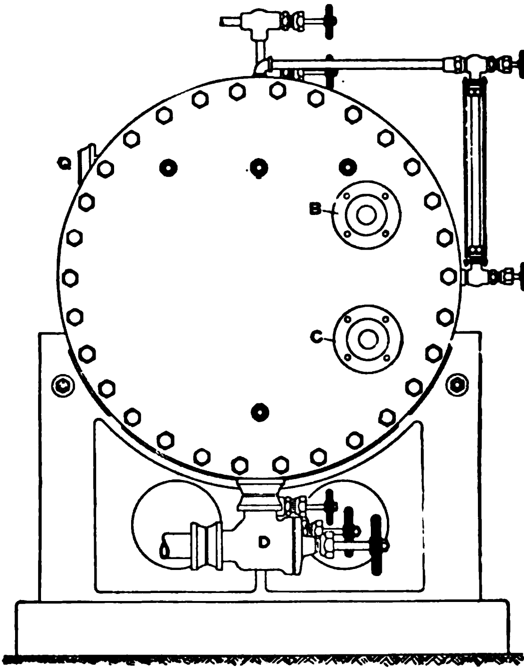
The coils should be kept clean by blowing them out occasionally with steam or compressed air, and where hard water is used this should be done at least once a week. In fact cleanliness and regularity of operation are the main things to look after in an absorption plant.

Why does the absorber sometimes show too high a pressure ?

There may be too much liquid in the system or too little cooling water ; it may also be due to permanent gases in the system.



The York Shell and Tube Absorber; for description, see opposite page.



The York Shell and Tube Absorber. In this absorber the gas enters at the bottom of the shell through the pipe and valve D. Inside of the shell the gas intake connects with a horizontal pipe O, which has a number of branches Y extending at regular intervals on both sides.

The branches are perforated at their bottom, as shown on the opposite page, and these perforations distribute the gas evenly over the entire apparatus.

The weak liquor also enters at the bottom at E. Inside of the absorber E connects with a horizontal pipe Z supplied with a number of branches X, which are so spaced that they come directly under the branches Y of the gas pipe O.

As the perforations in branches X are at their top, the incoming weak liquor is distributed in an upward flow, and is thus brought into direct contact with the incoming gas, thus, perfect absorption is assured.

The rising strong liquor circulates around the tubes P and is taken up by the ammonia pump, the suction pipe of which is connected to the flange Q near the top.

The equalizing pipe of the pump shown on page 344 is connected to S, thus any gas formed in the pump cylinder is returned to the absorber. The cooling water enters the head of the absorber at B, and after circulating through the tubes is discharged at C.

The purge pipe of the expansion coils is connected to F., by means of this pipe the expansion coils are cleared of any accumulated liquor.

K is a purge valve to blow off foul gas, and J is the pressure gauge connection. The absorber is charged through the valve G and may be pumped out through R, which connects to the pump suction.

The pipe G is connected to the discharge of the ammonia pump, but when the plant is in operation, pipes G and R are shut off by means of their valves. I is a drain for clearing the absorber of sediment.

What is one indication of the action of the absorber?

It can be noticed at any time whether the absorber is taking hold well by the frost on the gas pipe. If the frost continues white and keeps accumulating, the absorber is working uniformly; if the pipe begins to thaw, either the absorber has "let go," or the cooler has become foul.

Does the absorber require careful attention?

The efficiency of the machine depends upon the condition of the absorber. If the absorber is cool and free from air or foul gas, the cooler will give off its ammonia gas with ease.

How may purging of the system be done from the absorber?

At the bottom of the absorber is a purge valve. The pipe from this should have a swivel joint so it may be swung into or out of a bucket. If there is air in the system it will usually be found at the bottom of the absorber and should be drawn out through this valve. The valve should be opened occasionally to test the system for air. A clean machine ought to run from one to two months without trouble of this kind. To test it, get a bucket of cold water, and set it under the outlet to the pipe and open the valve from one-eighth to one-fourth turn. If air is present, bubbles will rise to the top of the water, nearly noiselessly. Should there be few bubbles, accompanied by a crackling sound, like water being heated with steam, it indicates the presence of gas, showing that that part of the machine is all right.

When air bubbles are rising, if a match is held over the pail and a pale yellow flame results, it shows that there is some foul gas mixed with the air.

Half way up the absorber there is another purge pipe for drawing off foul gas. If this valve is slightly opened and the gas issuing therefrom is lighted and continues to burn of itself, it shows foul gas.

How much aqua ammonia should be carried in the absorber ?

There is difference of opinion as to the amount of liquor to carry in the absorber to take up the gas coming from the freezing tank coils. The proper amount can be ascertained by testing the rich liquor passing through the ammonia pump at different heights in the absorber, that is, if the rich liquor indicates

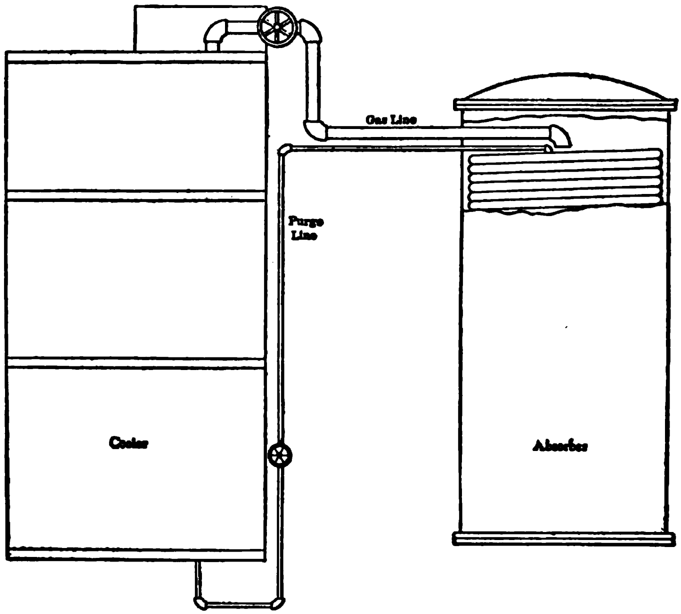
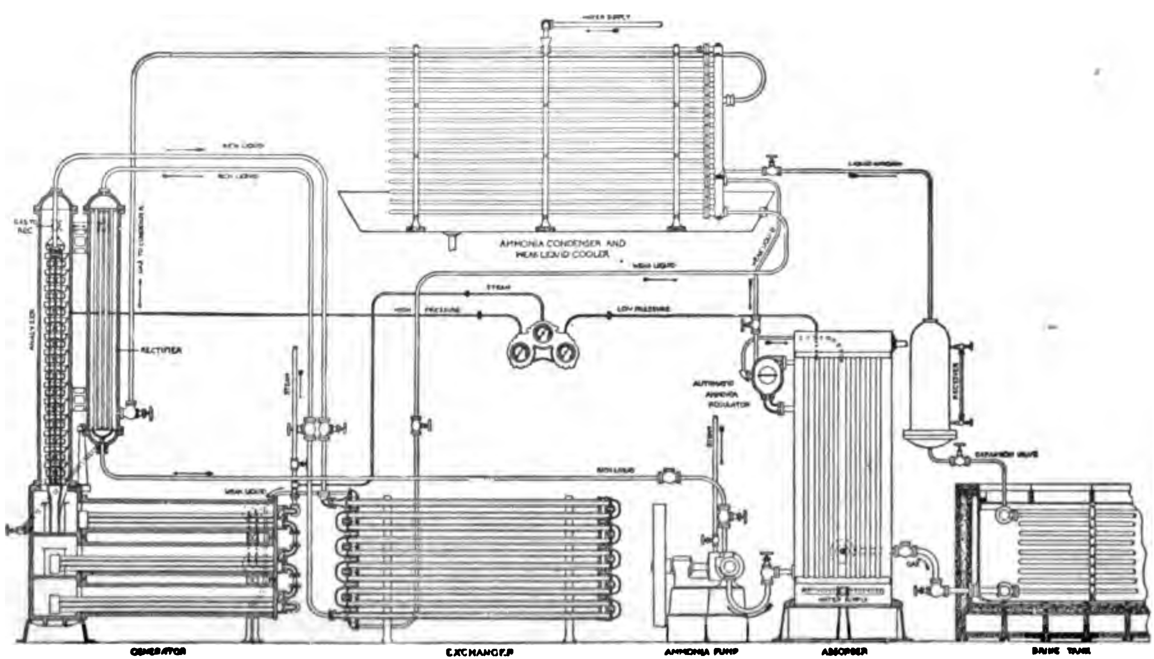


Diagram showing correct manner of connecting the purge pipe from the cooler to the absorber. (See page 343).

26 degrees at a certain height and 25 degrees at an additional height it is a sure indication that the limit has been reached, because the poor liquor absorbs all the gas coming from the coils and yet fails to bring the rich liquor up to the standard.

This is detrimental, for it requires more heat to extract the same percentage of gas from the 25-degree aqua ammonia than from 26-degree.



Sectional elevation of large absorption plant. In this system the rich liquor is circulated through the rectifier before passing through the exchanger, and thus some of the heat which would otherwise be carried off in the condensing water is saved.

What are the relative temperatures and pressures for the absorber ?

When the absorber is cold the poor liquor within it will have a large absorbing power and take gas from the cooler all right, even if it is gas of medium high percentage ; if it grows warmer, it will have less absorbing power and do less work.

If the temperature cannot be improved because of insufficient water or because of the high cost of the water, the liquor coming over must be made weaker, by turning more heat on the generator and distilling more of the gas over into the condenser, which will carry a large amount in storage. It will also be found that the cooler will need a little more gas under this condition. This weakens the whole charge in the generator, requiring higher heat in the coils and a higher pressure to distill the necessary gas from the weakened charge, and this is the reason a higher pressure has to be carried with a warm absorber.

With cooling water at or below 60 degrees, a low-pressure machine will run at atmospheric pressure ; with water at 70 degrees, the steam pressure may have to be raised two or three pounds ; and at 75 degrees it may have to be raised to 10 pounds. Some machines will require higher pressures, depending on the heating surface in the generator. With 60-degree temperature water the pressure in the generator may be from 90 to 100 pounds and at 75 degrees it will be necessary to carry it to 150 or 160 pounds. All these pressures are determined by the temperature of the absorber and whether coal or water costs the more.

If water can be obtained from driven or bored wells, an absorption machine can be run the year through with exhaust steam, and it will not act as a brake on the engine. Where there is lots of brine pumping by steam pumps it is possible to run a machine with the exhaust from the pumps.

Conditions as regards water should be carefully investigated before deciding on the site for a plant.

How may "dead" liquor be gotten out of the cooler into the absorber ?

While operating an absorption machine it sometimes happens that more liquor gets into the cooler than the absorber will take out, and frequently dead liquor lies in the bottom of the cooler.

The usual manner of getting this into the absorber is to shut off the return gas line from the cooler to the absorber and open a line from the bottom of the cooler to the absorber. This shuts down the machine during the process of pumping out, and the temperature of the brine goes up, often 10 degrees or more, and may require two to four hours. The liquor is evaporated and is taken up in the absorber by the weak liquor. Shutting down a machine for this purpose may really cause a high-temperature brine for several hours.

How may this difficulty be overcome ?

The pipe at the bottom of the cooler may be connected with the liquor line from the absorber to the pump by a one-inch pipe and a gate valve. It is understood that it would not do to attempt to open this valve wide or to attempt to pump it out unless there was a good amount of liquor going from the absorber, as the pump would refuse too rich liquor.

Giving two to two and one-half turns on this gate valve would clean out the cooler as quickly as the old way and the operation of the machine would not be interrupted, but the temperature of the brine would go down during the process. The machines should be run in the usual manner during this operation and nothing changed, except to partially open the valve at the bottom of the cooler, as described. It saves a lot of labor and keeps the brine temperature down.

It would be a good plan to provide this pipe with a check valve to prevent liquor from the absorber backing into the cooler.

Why not open the purge line from the cooler without shutting off the gas line from the top of the cooler?

The practice is to connect the purge line into the gas line between the valve and the absorber. This has been tried and found to work. It will not take out the dead liquor, or the accumulation of liquor, at the bottom of the cooler as quickly as by shutting off the gas line, but it will take it out without stopping the operation of the cooler or raising the temperature more than two or three degrees. The temperature of the brine has actually been found to be reduced during the operation. If there is a large amount of liquor in the cooler, the purge line will work all right for two or three hours, and then the purge line will commence to melt. When this occurs, shut off the purge line for half an hour, then turn it on, and it will start.

Can the purge line be connected up differently?

The purge line from the bottom of the cooler is connected to the gas line at the top of the cooler, and when both are working together they necessarily interfere with each other. The purge line may be put into the absorber separately. By such an arrangement the two lines would operate independently of each other, as shown in the illustration on page 339.

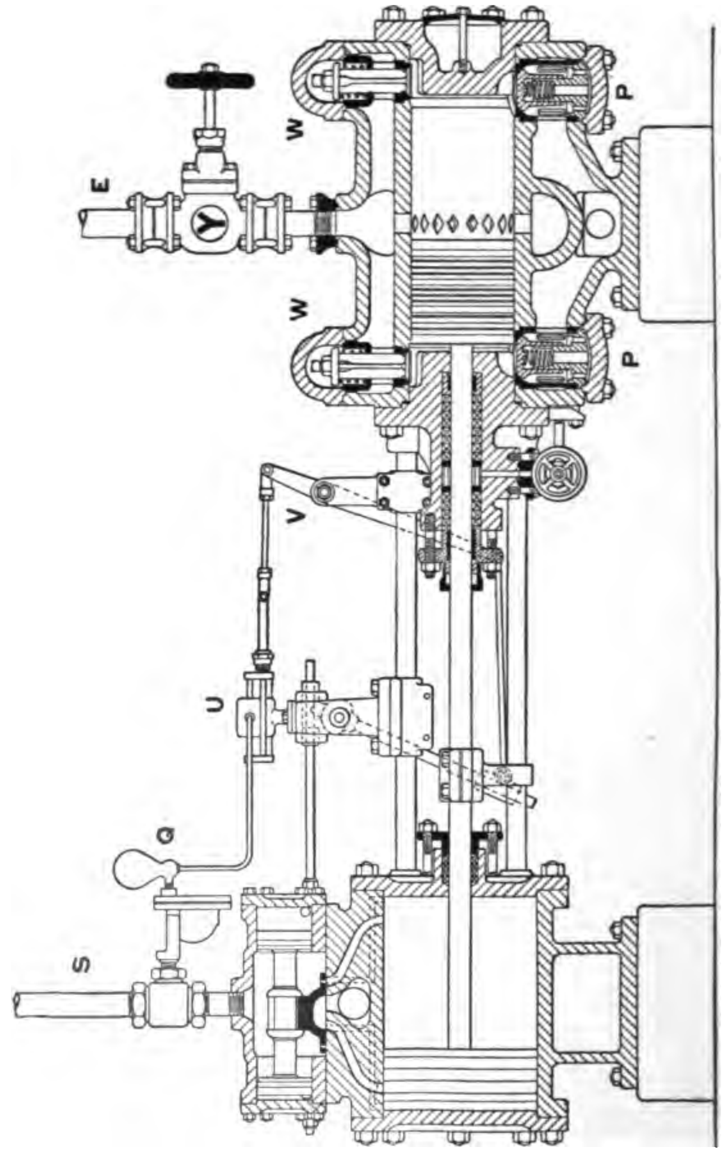
Is there any danger of freezing the water in the absorber coils?

Where low temperatures are carried, it may be necessary to carry the gas line inside the absorber and turn down in the center of the water coils, as, should the gas from the cooler strike against the coils, it would in many cases freeze them.

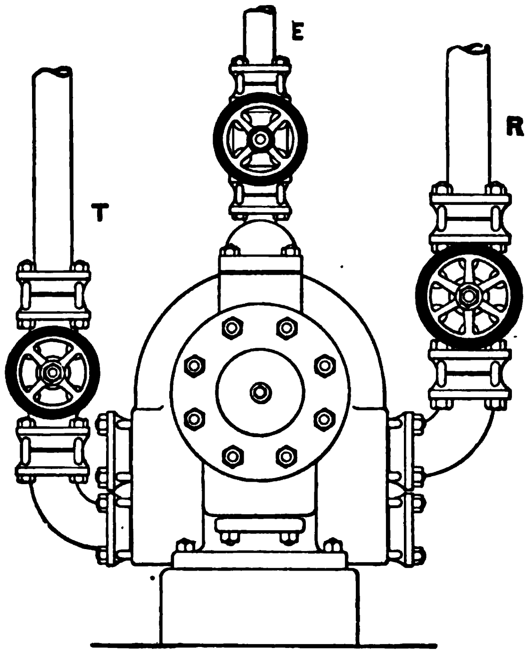
What is a remedy for the "boil over?"

Close the expansion valve very nearly, pump a vacuum on the absorber, and blow the gas through the coils. This generally cleans them and takes the ammonia back to the absorber.

If the expansion coils are divided into sections supplied by manifolds, one section at a time may be shut off and cleaned.



Sectional view of York double-acting ammonia pump; for description see opposite page



Description of Ammonia Pump on Pages 344 and 345.

S is the steam pipe supplied with the governor **Q**, the governor consists of a diaphragm which operates the governor valve. The small hydraulic cylinder **U** contains a piston operated by the piston rod through the lever **V**. When the speed of the pump increases, the pressure upon the diaphragm is increased by the hydraulic piston, and thus the governor valve is partly closed. The strong liquor enters the pump through the pipe **R** and the suction valves **W-W**, **P-P** are the discharge valves, and **T** the discharge pipe which leads to the heat exchanger. The pump cylinder is provided with a number of small ports around its center, which by means of the annular channel connect with the equalizing pipe **E**. At the end of the suction stroke the pump piston uncovers these ports, and any gas that may have formed during suction will pass through **E** into the absorber to which this pipe is connected. The pump in all cases must be set below the absorber.

What should be done in case of a "boil over?"

Though a careful engineer will see to it that the liquor level does not rise in the generator enough to cause a boil over or rush of liquid into the condenser and low side of the system, this accident sometimes does happen, and it is well to know what to do. Such an accident is shown at once by the frost becoming moist on the headers of the expansion coils between the tank and the expansion valves. When this occurs or the frost drops off, the liquor level in the generator should be noted at once, and if still high, the ammonia pump should be shut down until the proper level is restored. Where the freezing tank is elevated to give a gravity return to the absorber, this will be all that is necessary to be done, but otherwise the poor liquor valve on the absorber will have to be closed and the pump started to create a vacuum in the absorber so as to draw off the liquor from the expansion coils. After the coils are emptied, the weak liquor valve of the absorber is opened again and the pump is kept running in the regular or at reduced speed if necessary to keep the liquor in the generator at the proper level and prevent its rising to an undue height. As the temperature of the tank will rise during the righting of the distribution of ammonia in the system, the machine will require special attention until normal conditions are restored.

As the conditions are established, the amount of ammonia liquor in the system should be adjusted so that it will give the best conditions of operation, and this will be the case when the gauge of the ammonia in generator and absorber stands about full under normal operating conditions.

What is the only moving piece of machinery in the Absorption system ?

The ammonia pump, as said before, which is used to take the rich liquor from the absorber and force it through the heat exchanger into the generator.

Is the pump specially constructed ?

Yes, because ammonia must not be allowed to leak in the stuffing box. It is a small pump, however, and designed to run at moderate speed.

What is the rate of speed for an ammonia pump in a 50-ton ice plant ?

Forty to fifty strokes per minute.

How much steam does the ammonia pump require ?

Generally from one-fifth to one-seventh of what is required in the generator.

What is done with the steam from the pump ?

It may be used to heat the rich liquor after it leaves the exchanger on the way to the generator, and also utilized for distilled water.

How should the ammonia pump be placed ?

Below the level of the absorber so that the liquor will run in by gravity.

Why is this necessary ?

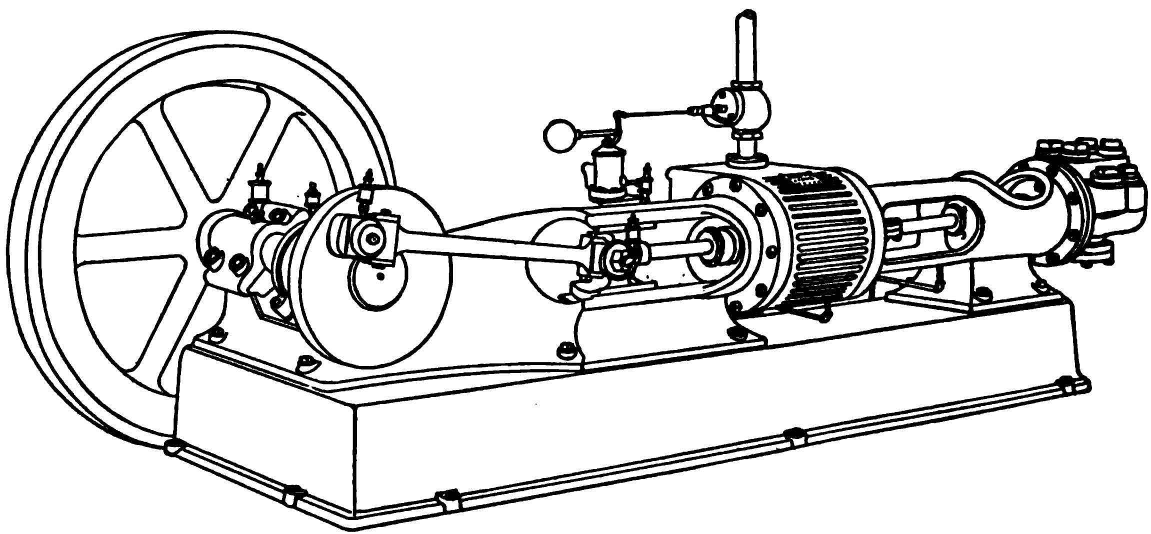
Because if the pump had to exert any lifting power it would create a slight vacuum and liberate some of the gas, thus making the pump gas-bound.

What difficulty do we sometimes have with the ammonia pump ?

It becomes "gas bound"; that is, it becomes filled with vapor from the strong liquor and refuses to work.

Is it possible to avoid this difficulty ?

In the design of a pump, as shown on page 344, an equalizing pipe is provided to allow any gas that may have formed to return to the absorber.



Ammonia pump for returning the rich liquor from the absorber to the generator in a 200 ton absorption plant.

What is sometimes found to be the reason for this difficulty?

The pump may be placed too high; if it be lowered the liquid will flow in by gravity.

What is important in the management of the ammonia pump?

The thoroughness advised in overhauling the water pumps will also apply to the ammonia pumps. It frequently happens that it is a hard matter to keep the pump from knocking, almost invariably caused by insufficient flow of rich liquor; by adding another suction pipe of the same area opposite the present one on the absorber, and enlarging the fittings at the pump to the area of both pipes it will insure a full flow to each side of the plunger and stop the noise. Another way is to enlarge the present suction pipe to double the area.

It is well to have a small connection from the poor liquor pipe to the suction pipe somewhere near the absorber, so that in case the pump gets gas bound it can be remedied by simply opening the valve for a few seconds to charge the pump, thus saving the possible necessity of stopping the pump, removing the valve caps and charging the pump in that way.

Describe an emergency method of packing an ammonia pump.

There is probably no one matter calling for the engineer's immediate attention, and at the same time more exasperating than an irreparable leak of the ammonia or large water pump during the busy season, because it means expeditious work, and at best, the chances are that the brine will go up several points; hence, any method or material that will reduce the conditions to a minimum is most welcome to the engineer.

☞ The packing of one of the ammonia pumps gave out on Sunday and there was none to take its place. The engineer went to a near-by junk shop in quest of something, but found only an old rubber buggy tire; this he shaped nicely to fit the stuffing box, and it worked so well that he fixed the other two ammonia pumps and both large water pumps in the same manner. They ran the entire season without additional packing, and the cost for packing of the five pumps for the season was 45c., to say nothing of the extra comfort of the engineer.

What is the design of the ammonia pump ?

It has been made single acting, usually, on account of the difficulty in keeping the stuffing box tight ; the York pump, mentioned on page 344, however, is double-acting.

What advantage has an absorption machine in the way of foundations ?

The ammonia pump being the only moving part heavy foundations are not required.

What is the Heat Exchanger or Equalizer ?

An apparatus of the shell and coil or double pipe type. It is for transferring heat from the weak liquor of the generator to the rich liquor coming from the absorber. The former may be 280 degrees and the latter 80 degrees.

What are the workings of the Heat Exchanger ?

The weak liquor coming from the lower part of the generator is very warm, while the strong liquor coming from the absorber is cold, so that as a matter of economy it is desirable to transfer as much as possible of the heat of the former to the latter. This apparatus may be arranged somewhat like a double pipe condenser, or by coils in a vertical steel cylinder, the poor liquor passing in at the top while the pump forces the rich liquor up through a coil and out at the top.

What is the essential principle of its operation ?

The two liquors are passed through separate coils in close proximity to each other, or one coil may be inclosed within the other.

In all apparatus for exchanging of heat how should it be arranged ?

That the flow should be in opposite directions ; called the counter current plan. (See page 213).

How may a leak in these coils be detected ?

A leak in the exchanger coils is one of the defects that the engineer locates while making his regular round of inspection and test. Ordinarily the rich liquor should show 28 degrees, while the poor liquor is 16 degrees. This shows excellent working and in some cases the plant may not show these results. When the engineer finds that the strength of the rich liquor is 24degrees, while the strength of the poor liquor has fallen in like proportion, he knows at once that the machine is doing the proper amount of work, but at the cost of extra fuel, as required to distill the rich liquor of lower density. Then again when the test of the rich liquor shows a density of, say, 24 degrees, while the density of the poor liquor rises, the indications are of an exchange of ammonia, which means a leak in the exchanger coils. If the leak is not mended the exchange will go on until the density of the two liquors in the system is equalized.

How strong should the heat exchanger be constructed ?

It should be able to stand the same pressure as the generator the pressure being regulated by a valve on the poor liquor pipe which is the high pressure side.

What should be the capacity of the heat exchanger ?

According to Starr's calculations, about 120 square feet for an ice making plant of 10 tons capacity.

How is the exchanger pressure regulated ?

By a valve on the poor liquor pipe coming from the retort or generator.

What is the Weak Liquor Cooler ?

A vessel used for the purpose of doing for the weak liquor the reverse of what the heat exchanger does for the strong liquor, that is take the heat out of it ; it may be of the shell and coil, or double pipe type.

What is the Heater ?

A part of the apparatus frequently used as an auxiliary to the heat exchanger.

It is essentially a coil of pipe through which the rich liquor passes from the heat exchanger on its way to the generator. It is of the shell and coil type, the liquor passing through the coil and taking up heat from the exhaust steam of the pump.

Does the operation of an absorption machine require very careful adjustment and regulation ?

In the absorption machine the successful operation of the plant depends altogether on how the engineer regulates his pressures and temperatures.

One must have adaptability to conditions, as small differences have a great bearing in the operation of the machine. Thus a plant having water several degrees cooler than others will operate at different pressures throughout, and act differently with different changes of conditions, and the engineer must be quick enough to anticipate the results of these changes. In the same way the design of the machine is vital and an engineer familiar with one type may, if he is not versatile and readily capable of adapting himself to the changed conditions, have considerable difficulty in taking hold of a different style of plant.

Strength of the solution is governed by the steam pressure admitted to the coils, the heating surface of the coils, size of condenser, the amount and temperature of condensing water, and the required temperature of the brine. The temperature of the solution will be raised nearly to that of the incoming steam, so that the generator pressure corresponding to any temperature depends upon the strength of the solution and the temperature of the condensing water. As the temperature of the solution is below the boiling point of water at generator pressure, it is natural to assume that no water evaporates, but there is a large amount carried over with the gas.

What does the working plan of the absorption system resemble ?

It is similar in principle to the vacuum machine, but it is found to be more satisfactory and economical to use a liquid which will evaporate at a low temperature without the aid of a vacuum. The vapors instead of being absorbed by sulphuric acid are taken up by water. They are separated again by distillation, and then liquefied by pressure in the condenser where the temperature is reduced by cooling water.

Where is the absorption machine favored ?

In the demand for low temperature work, under which in many cases, an absorption plant can be more economically installed and operated than any other type.

These machines are designed to operate with steam pressures from five pounds upward, either using live steam direct from the boiler or exhaust steam from auxiliary machinery. In special cases where large quantities of exhaust steam are available, lower pressures than five pounds may be used.

What is one advantage of the absorption system ?

It may be operated by exhaust steam ; and if an abundant supply of cooling water at about 55 degrees is available, the conditions are very favorable for the installation of an absorption machine.

How does the Absorption system compare in economy with the Compression system ?

As for economy of operation, it is as economical as the compressor from 10 degrees F. to zero F., while for temperatures below zero it is somewhat more economical, as the cost of operation with the compressor increases considerably when the zero point is passed. This depends very much on the temperature of the cooling water.

What errors in the operation of an absorption machine should be avoided?

If anything gets out of order, or the capacity falls down, the operating engineer frequently raises the steam pressure and speeds up the ammonia pump. The result is that he attains the old capacity but at a great loss in efficiency. The ammonia gas goes through the analyzer and dehydrator or rectifier at relatively great speed and the amount of water vapor carried through is large. This in turn condenses and clogs up the condenser and cooling coils and diminishes refrigeration very greatly. The result is that the engineer in turn is apt to speed up the dehydrator; that is, increase the flow of the water over this, or diminish its temperature, if possible. This means that the water vapor, which is condensed absorbs in turn a large amount of ammonia gas, it also takes the heat from the ammonia gas. It can be readily seen that the generator is merely a heat receptacle, with a large number of leaks for heat loss. In reality the only heat removal from the generator should be in the steam condensation, in the ammonia gas, and in radiation losses.

When it condenses and drags back with it ammonia gas, it also takes the heat from the ammonia gas, which was put in it for the production of refrigeration. Thus, the action of the absorption machine presents wide possibilities for an operating engineer to go wrong. Almost any of the symptoms that show inefficient operation, or at least presenting signs that would warrant investigation or repair, can be completely removed or eradicated by the operating engineer without loss in capacity, but with a tremendous loss in efficiency of operation. These latter, going off in the cooling water, are not perceptible to the ordinary owner on inspection, and the result is that the absorption system often acquires a bad reputation when the plant itself possesses efficiency of a very high type when properly operated.

Are compression plants liable to such difficulties ?

Both the absorption and compression types of refrigerating machines are either efficient or inefficient, dependent upon design and operation. A compressor, with very large clearance and leaky valves, will produce little or no refrigeration and will have a very large steam consumption. The absorption system, with bad design and poor operation will, in turn, produce little or no refrigeration, since all the ammonia gas may be re-absorbed by condensed water in the dehydrator or water collected in the ammonia condenser proper. The operating engineer who would allow his compressor to get out of order to the extent that the valves never closed completely and, further, did not keep enough ammonia in the receiver to prevent passage of the ammonia gas through the expansion valve could not be praised. Exactly similar conditions to this exist every day in the operation of the absorption plant, and it is only due to the fact that the machine can be speeded up to counterbalance these defects, and that the defects themselves are invisible or at least not perceptible to the ordinary senses, that they are not at once self-evident.

How are different working conditions sometimes provided for ?

In the Plaza Hotel, New York, it was desired to put in a 100 ton plant, in duplicate, but instead of installing two machines of the same type, one absorption and one compression machine were put in. During the fall, winter and spring, when there is plenty of exhaust steam, and cool water available for condensing purposes, the absorption machine is operated ; in summer, when live steam must be used, and condensing water is warm, the compression system is used.

How long does the test of a plant usually take ?

Official tests are not usually less than twenty-four hours and they may be extended over several days.

Describe an approved method of charging an absorption plant ?

It will be presumed that the plant has been steamed out and tested, and is ready for charging and starting up. If the system is left under a vacuum after steaming out, aqua ammonia may be forced into the absorber by atmospheric pressure, otherwise it is pumped in by the ammonia pump. The plant should be provided with suitable by-pass and piping connections to make this possible. The end of the suction pipe is inserted in the bung-hole of a 750 pound aqua ammonia drum, to within one inch of the bottom of the drum, and the valves on the piping between the drum, the pump, and the absorber are opened, when the pump is started and the liquor forced into the absorber. During the process of charging the aqua ammonia drum should be kept as cool as possible. From the absorber the ammonia liquor is pumped into the generator until the level shows the proper height by the gauge glass or gauge cock as may be used. The liquor level in the absorber gradually rises and may at first stand about at the top of the glass, though it is not well to charge too much ammonia at first.

Now the valves between the analyzer and the condenser, and those on the weak liquor pipe from the generator to the absorber, are opened and a little steam is admitted to the generator coil.

The water pumps are now slowly started to put cooling water over the condenser coils and through the absorber, and as soon as the generator warms up and the liquid level begins to fall the ammonia pump is started to supply more ammonia from the drum, care being taken, however, not to pump too much ammonia into the generator so as to cause a "boil over." If the system has not been steamed out the air valve must be opened at times to let the air escape while the gas is being generated, care being taken not to allow the gas or ammonia liquor to escape.

More steam is gradually admitted to the steam coil of the generator, and the ammonia is charged into the system as the operation goes on until the level begins to rise in the absorber

to the height desired. The pressure now in the generator will be about 100 to 120 pounds. The ammonia pump is then disconnected from the charging drum and the connection made from the absorber to the generator in the usual way. With water going over the condensers, the gas formed in the generator will be condensed and passed to the liquid receiver, and with a pressure of from 120 to 130 lbs. in the system the expansion valve may be opened a little. If the frost formed upon opening the valve is dry, leave it open and get more pressure by turning more steam on the generator coil.

In a short time the ammonia pump which is kept running slowly all the time will lower the liquid level in the absorber until it stands at the bottom of the glass, and then more ammonia liquor should be pumped into the system either to the absorber or into the generator so that the level may be maintained. It is not well to have it higher than this at the start until the conditions of the plant are fully established. When it is found that there is not sufficient ammonia in the system, more can easily be added, but it may make trouble if too much should be charged at once.

How does the purpose for which the plant is used affect the management?

The purpose for which a plant is used and the character of trade supplied has a considerable bearing on the problem encountered by the engineer. Thus, where it is the policy of the management in a comparatively small plant to shut down at night and start up in the morning, the engineer must look out for things that he would not have to contend with in a plant that was in operation twenty-four hours every day. For one thing, he must watch the temperature of the ice tank and keep it lower than the freezing point during the shut-down period, for if he does not, the ice in the cans will begin to melt, and when re-frozen the water will bulge the cans and ruin them.

What course is recommended in adding to the charge in a machine ?

This subject is intended mainly to apply to charging absorption refrigerating machines, but many of the general principles set forth are also applicable to charging the compression machine. The lack of application of a knowledge of the properties of anhydrous ammonia as to temperature and pressure, and of aqua ammonia as to the relation of temperature, pressure and strength of the aqua, often leads to expensive and sometimes disastrous results when the operation of recharging with anhydrous ammonia, or adding to the charge, is concerned.

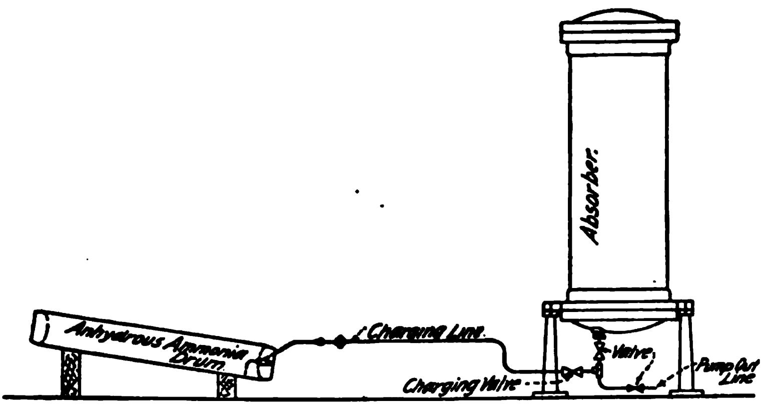
To what custom is this fact due ?

It is a habit in a great many plants, especially in cold storage warehouses, to keep a reserve stock of anhydrous on hand in cold storage rooms where the temperature, and, therefore, the pressure, of the anhydrous ammonia may reach a point considerably below the pressure existing in the pipe through which it is charged. Numerous examples have been brought to notice where anhydrous has been kept in a room at a temperature of, say, 5 degrees above zero, and then an attempt made to take out the drum and discharge it against a pressure of 20 to 25 pounds. As the pressure of anhydrous ammonia at 5 degrees above zero is about 20 pounds it is quite plain that instead of the anhydrous being discharged into the machine under circumstances such as described, an exactly contrary effect may happen, and the cylinder, instead of discharging contents, may receive from the machine either aqua or anhydrous, and so completely fill the cylinder, leaving no gas space for expansion.

Cases have been known where the cylinders were kept outside at a temperature of zero, or below zero, and then an attempt made to empty them against a pressure of 15 pounds or more. It is, of course, impossible to do this unless the pressure is lowered in the pipe or vessels through which it is expected to be discharged, or else the cylinder be warmed.

Can one tell whether a cylinder is receiving a charge without weighing it ?

Some engineers judge from the frost on the cylinder on the theory that the disappearance of the frost indicates that all the liquid is out of the cylinder and only gas remains. This is a safe inference in charging a compression machine where the charge is admitted to the suction of the compressor (providing



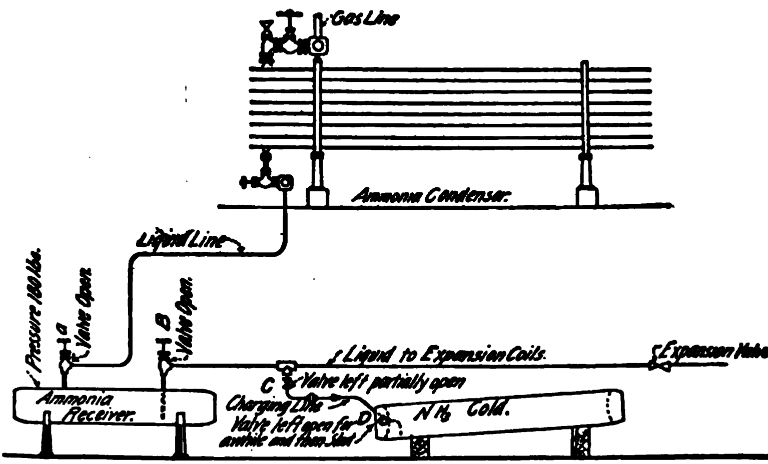
A safe way of charging a plant, but the refrigerating effect of the cylinder full of ammonia is lost.

the return pipe is not frosted), because no anhydrous can work back—but it is by no means a safe inference when the anhydrous is discharged into an absorber, as shown on this page.

The appearance and subsequent disappearance of the frost under the conditions as shown above, is more likely to be a sign that the anhydrous has first left the cylinder, and after the pressure balances are equalized, a little aqua flowing back will immediately collapse the remaining gas in the anhydrous cylinder, creating a vacuum sufficient to draw aqua back into the cylinder and even to fill it.

Is it advisable to use a check valve ?

Sometimes it is for many reasons desirable to discharge into the absorber instead of discharging in the manner shown on pages 361 and 362, but in such cases a check valve should always be used on the charging line. It is not unusual to charge either a compression or absorption machine in the manner shown on this page, but the effect of work done on the ammonia at the ammonia factory is preserved.

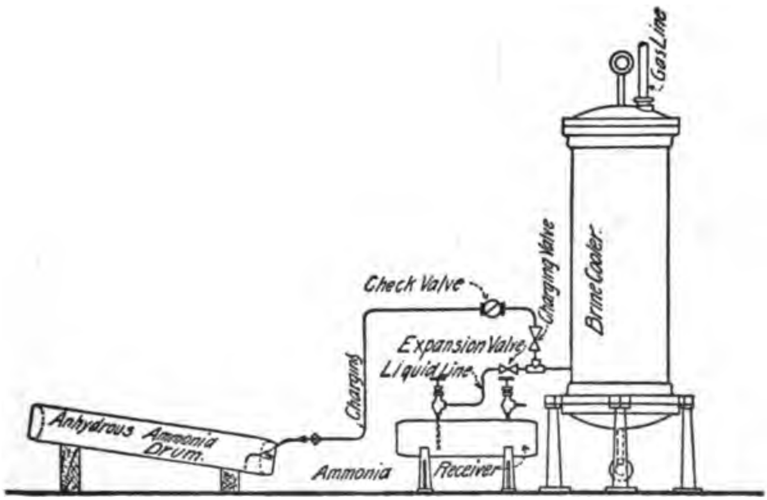


A more dangerous way of charging a plant, but the refrigerating effect of the ammonia is preserved.

However, even in the cases shown on pages 361 and 362, it is excellent practice to put a check valve on the discharging line, so that in case the cylinder of anhydrous may not be closely observed when nearly empty there will be no danger of anhydrous flowing back into the cylinder after the pressures are equalized.

In charging, what fact should be taken advantage of ?

It is desirable, all other things being equal, to charge the anhydrous ammonia in such a manner that it will perform effective refrigerating work, or, in other words, to put into useful effect the work that has already been performed on it in the way of liquefying it at the ammonia factory. This item is not always so large as to offset other advantages of convenience, position of existing connections, etc., but it is an

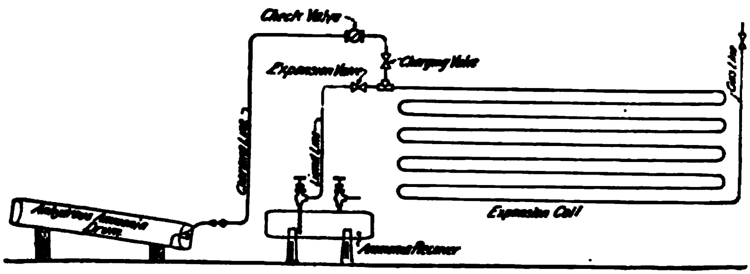


Correct way of charging a plant equipped with brine circulation.

item that is of value when it is just as easy to discharge the drum on the low pressure side ; that is to say, between the expansion valve and the expansion coil or cooler, or directly into the body of the cooler. As a concrete example, the charging of 1,000 pounds of anhydrous in a manner that would permit it to take up heat would amount to a useful refrigerating effect of from 3,000 to 3,500 pounds of ice melting. This effect would be lost in discharging into the suction of a compressor or into the absorber of an absorption machine.

What course does this make advisable ?

It would be better to discharge the anhydrous ammonia into an absorption machine (or even a compressor) as shown on pages 361 and 362. In these cases it will be observed that the charge is added to the machine on the low pressure side between the expansion valve and the expansion coils, and the work done on the ammonia at the ammonia factory is preserved.



Correct way of charging a direct expansion plant.

However, even in these cases, it is excellent practice to put a check valve on the discharging line, so that in case the cylinder of anhydrous may not be closely observed when nearly empty there will be no danger of anhydrous flowing back into the cylinder after the pressures are equalized. It is a common practice to watch the ammonia cylinder near the last end of the charging for the appearance of frost on the cylinders, due to the expansion of the last of the small amount of liquid that will remain in the cylinder under the end of the syphon pipe.

Some engineers will wait until frost appears, and conclude that the cylinder is empty, but if the engineer is called away about the time the frost appears, it may be possible that after the equilibrium of pressures is established, ammonia already in the machine will trickle back and make the cylinder a part of the expansion system. In this case the frost will persist.

What must be considered in choosing a type of machine?

In making selection of a machine for any given place, the three principal points to be considered are practical difficulties in operating, economy in water consumption, economy in steam consumption. In regard to the first, while the absorption machine is the simpler from a mechanical standpoint the cycle of operation is more complex and more likely to get out of balance.

Each stroke of the compressor does a certain amount of work, while, with the absorption machine, changes in steam pressure and temperatures in different parts of the apparatus may, unless carefully watched, disarrange the entire system. Manufacturers of absorption machinery, however, claim that improvements in recent years have overcome these difficulties to a large extent. It is probably fair to say that either type of machine when properly constructed and operated will give satisfactory results.

What special information is necessary to enable a manufacturer to decide which of the two systems is most desirable under given conditions?

Temperature of cooling water, and abundance of supply.

Boiler pressure of steam available.

Exhaust pressure of steam available.

Where is an absorption system indispensable?

In a direct expansion street pipe line where there are great variations in the load, it being much greater during the day than it is at night.

In erecting an ammonia plant how should the pipe and fittings be cleaned before they are put in position?

They should be well hammered and blown out by steam to remove scale, dirt, etc.

If water should be decomposed as claimed what chemical combinations might result ?

The hydrogen might combine with the carbon contained in the iron thus forming carburetted hydrogen which would burn, and the oxygen of the water might combine with the iron and form oxide of iron.

Do we find oxide of iron in absorption plants ?

In cleaning out a generator a considerable amount of black greasy sediment is often found which is black oxide of iron mixed with lubricating oil; the oil undoubtedly entering the still through the piston rod of the aqua ammonia pump.

What is permanent gas and how is it formed ?

It may be air which is drawn in through leaks, but it is more likely to be hydrogen and nitrogen due to the decomposition of ammonia, and the fact that it will burn when drawn off seems to favor this theory.

In the cycle of operation in a refrigerating plant the ammonia is continually undergoing the most extreme conditions of heat and cold and a possible electrical excitement, all of which are aids in hastening a tendency to decompose. The substances usually making up the impurities in anhydrous ammonia are salts of ammonia, methane, ethene, acetylene, carbon monoxide, carbon dioxide, propylene, vapors of benzol, toluol and ethane, sulphureted hydrogen, etc. All these decomposed and foreign gases are commonly called air or foul gas.

It is also attributed by some engineers to the decomposition of water, probably through electric currents. We find a very good indirect proof of this opinion in the fact that operators of absorption plants find in their stills quantities of oxide of iron. Ammonia contains no oxygen, and we have to look to water as the source from which the oxygen originates, the water being decomposed into its constituents, oxygen and hydrogen.

Is this permanent gas a serious disadvantage ?

An idea of the enormous loss of power may be obtained from the fact that decomposed ammonia (nitrogen and hydrogen) furnishes only about 9 per cent. of the refrigerating effect that pure ammonia furnishes; in other words, they require over eleven times more power to produce a given refrigerating effect than they do when combined as ammonia. Upon evaporating impure ammonia a pale, yellowish fluid remains which is called the water of ammonia. This consists partly of a heavy mineral oil, which is the lubricating oil found mixed with the black oxide of iron. It also consists of some of the varieties of alcohol, all of which are highly inflammable and decompose easily.

Why is quality important in ammonia ?

Impurities are very objectionable because they cause permanent gases, and also because pyridine impurities have a tendency to dissolve rubber gaskets and packing which are largely used in refrigerating plants.

How can aqua ammonia be tested ?

By chloroform because it has a greater affinity for these impurities than ammonia has, and being heavier than water it sinks to the bottom taking the impurities with it. Then the chloroform may be evaporated leaving the impurities which may be detected by their odor.

Why should care be taken in disposing of foul gas ?

Hydrogen is an inflammable gas, and so is generally the foul gas forming in absorption plants. The removal of this foul gas from a system may be the cause of a serious loss of ammonia. Pure ammonia gas blown from a small valve opening cannot be ignited, but if a lamp or candle is held near the opening the heat is sufficient to decompose part of the ammonia into hydrogen and nitrogen, the amount of decomposition depending upon the size and heat of the flame. The hydrogen gas may

burn with a peculiar wavering flame. As soon as the light is removed this will stop. Many operators of absorption machines believe that if the gas which escapes from a purge valve on the condenser burns, they remove only foul gas from the system. This is a mistake. A number of experiments with various mixtures of hydrogen and ammonia gas show that a mixture 15 per cent. hydrogen gas and 85 per cent. of ammonia gas, by volume, can be ignited and will readily burn. The flame appears to be hot enough to decompose the entire amount of ammonia gas in the mixture, as no ammonia smell can be noticed. This means that if an operator of an absorption plant removes from his condenser in this manner one cubic foot of foul gas he may at the same time remove from it five cubic feet of ammonia gas.

Are absorption plants more liable to have foul gas than compression systems ?

Abnormal consumption of ammonia in absorption plants is undoubtedly due to the same cause as in compression plants, namely, to leaks. But absorption plants appear to have one specific difficulty to contend with, and that is the formation of so-called "foul gas," which is a non-condensable gas collecting in the condensers and occupying valuable space.

Are thermometers and pressure gauges necessary in refrigerating machinery ?

Thermometers and pressure gauges should be provided on all principal parts of the absorption machine and the engineer should take great care to use them. Gauge cocks and gauge glasses on the absorber are also convenient but there is some question as to the use of a gauge glass on the generator owing to the danger of breakage at high pressure. With a properly constructed glass, however, there should be no danger.

How closely should temperatures be read ?

To tenths of a degree.

What matter should be guarded against in charging?

The ammonia liquor being put in when cold, expands when heated so that care must be taken not to overcharge.

How should an absorption plant be re-charged?

If the original charge was 4,000 pounds at 26 degrees Beaumé, it would consist of 1,040 pounds ammonia in 2,960 pounds of water. If the gas has leaked out or the liquor become impoverished, and the hydrometer shows only 23 degrees Beaumé, there is 120 pounds missing. In this case put a drum of anhydrous on a scale and connect it with a rubber pipe to, say, the feed pipe to the freezing tank; when the desired charge into 10 or 15 pounds has run into the machine close the valve and work the machine for an hour or two, then add the amount held in reserve and the plant should work right along.

How may leaks of ammonia be detected?

There are various devices for detecting leaks, but the best is white litmus paper. This can be procured free from the dealer in ammonia. Take a strip ¼ inch wide and about 1½ inches long. With a thread, tie it on a small stick 15 to 18 inches long. When using it, moisten it in water and hold it to the suspected place. If there is a leak the paper will turn red and the shade of red will show how strong the leak is. Litmus paper will detect leaks that cannot be smelled. Turn it away from the leak into pure air and it again becomes white. It can be used until completely worn out, all that is necessary, when using it, being to moisten it. (See also page 230).

What is a good protection against ammonia leaks?

Workers around ammonia should not forget the strong affinity it has for, and the absorbing power of, water. When there is even a small leak of the gas under pressure, a piece of water-soaked waste put over it will remove all trouble until the water is thoroughly saturated with it.

It is a good idea to practice using water for even unimportant leaks so as to be accustomed to it. A 1-inch hose and a 2½-inch hose under water pressure should always be handy, as by their use a big leak could be drowned.

How is the air expelled in charging a machine?

One method is to open all the connecting valves leaving one open to the atmosphere, then introduce live steam into the retort until all the air is blown out, then close the open valve and let the steam cool down and condense, which will make a vacuum. But the steam will soften rubber joints.

A better plan is to pump a vacuum, say of 25 inches, by the ammonia pump. Then connect the charge pipe with a drum of aqua, taking care not to let any air enter the pipe when the drum is empty. Then empty another drum until the vacuum in the machine is gone, then pump in the rest by the ammonia pump until the charge is nearly complete. Then heat the ammonia by slow degrees by turning steam through the heater coils. When the gauge pressure has gone up to 100, more or less, open the purge cock, and stop when no more bubbles come up through the water. Then turn condensing water on the condenser coils, cooler and absorber, and apply steam until liquefied gas shows in the gauge. Then open distributing valve to freezing tank and turn the poor liquor into absorber, and in a few minutes the ammonia pump may be started to pump the enriched liquor through the coils of the exchanger and into the retort. Let the condenser steam into the re-boiler and allow cooling water to run over the distilled water cooler coils. Let it run out until the water becomes clear and tasteless. Proceed in this way, carefully watching for leaks at the joints, until it seems to be tight everywhere, and the pipes in the freezing tank become coated with frost. Then close down and make the brine solution, and on starting the machine again the rest of the ammonia may be put in.

How may the specific gravities of samples of ammonia be tested ?

By Beaumé scale as in table below ; by drawing off some of the liquid in a tall test tube, the Beaumé hydrometer (light) may be inserted and the specific gravity read upon the scale. If water is present, the liquid will show a density proportionate to its percentage.

TABLE OF SPECIFIC GRAVITIES AND PERCENTAGE OF AMMONIA (CARIUS).

Degrees Beaumé	Specific Gravity	Percentage	Degrees Beaumé	Specific Gravity	Percentage
10	1.000	0	21	.9271	19.4
11	.9929	1.8	22	.921	21.4
12	.9859	3.3	23	.915	23.4
13	.979	5.	24	.909	25.3
14	.9722	6.7	25	.9032	27.7
15	.9655	8.4	26*	.8974	30.1
16	.9589	10.	27	.8917	32.5
17	.9523	11.9	28	.886	35.2
18	.9459	13.7	29	.8805	....
19	.9395	15.5	30	.875	....
20	.9333	17.4	..	.....	....

* Called by the trade 29½ per cent.

How are corrections made for temperature in ascertaining the quality of aqua ammonia ?

Deduct from the readings the amount shown by the table if the temperature of the aqua is over 60 degrees Fahr. If the temperature is under 60 degrees, add to the reading.

One degree Beaumé for every 35 degrees Fahr., for 16-degree aqua.

One degree Beaumé for every 30 degrees Fahr. for 18-degree aqua.

One degree Beaumé for every 25 degrees Fahr., for 20-degree aqua.

One degree Beaumé for every 21 degrees Fahr., for 22-degree aqua.

One degree Beaumé for every 17 degrees Fahr., for 24-degree aqua.

One degree Beaumé for every 13 degrees Fahr., for 26-degree aqua.

To take a specific instance, if the weak liquor leaving the still is 18 degrees Beaumé and 90 degrees Fahr., in temperature, deduct one degree Beaumé for every 30 degrees Fahr. over 60, which will make the corrected strength 17 degrees Beaumé.

What is the specific gravity of anhydrous ammonia?

Specific gravity of pure anhydrous ammonia is .623.

If the rich liquor should decrease in strength and no ammonia be available how may the plant be brought up to capacity?

More heat will have to be applied to the generator; it has, however, been demonstrated that it is more satisfactory to increase the speed of the ammonia pump and not distill so low. Either of these methods, however, should not be continued for any length of time as they are not economical, and should only be tolerated in case of emergency.

Is the steam from the generator of an absorption machine sufficient for an ice plant?

Some additional live steam is also required.

What is the average horse power required to operate the ammonia, brine, and water pumps, where an absorption system uses exhaust steam?

It is usually under one-third of a horse-power per ton of refrigeration.

How does this compare with the power required by a compression plant working under similar conditions?

It is less than one-fifth the power necessary in a compression plant.

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